AIR POWERED CARS
BY TERRY MILLER

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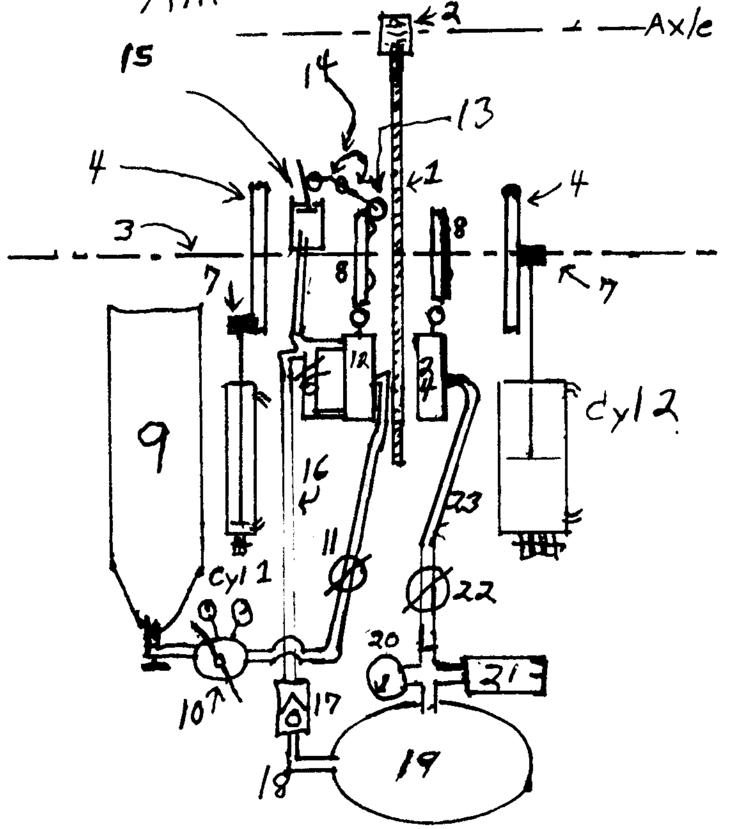
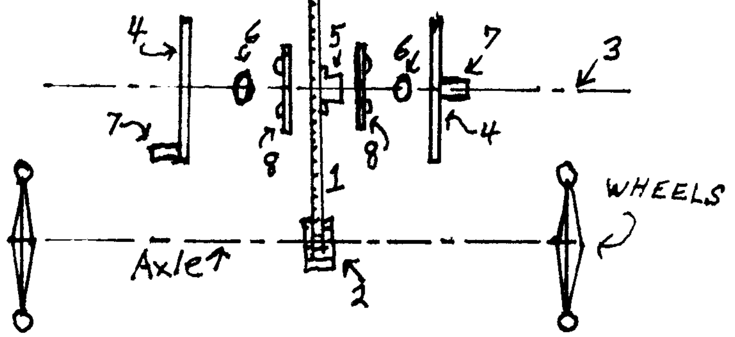
AIR SYSTEM LAYOUT

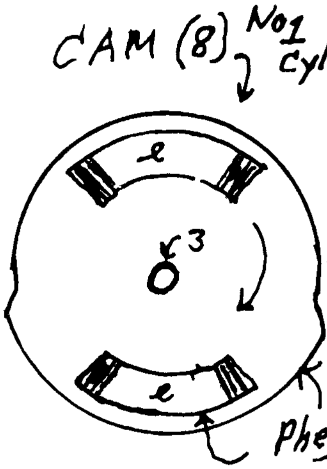


Air Powered Vehicle
INVENTOR Terry Miller
DISCLOSURE Oct 5th
1979

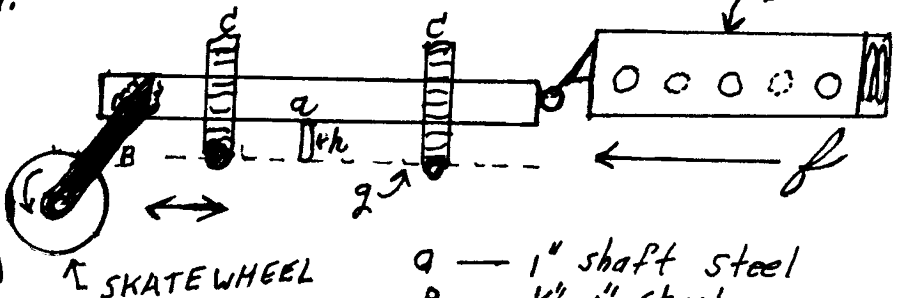
TIMING CAM — CRANK SHAFT & GEAR LAYOUT



Air Car One. Valve timing Layout



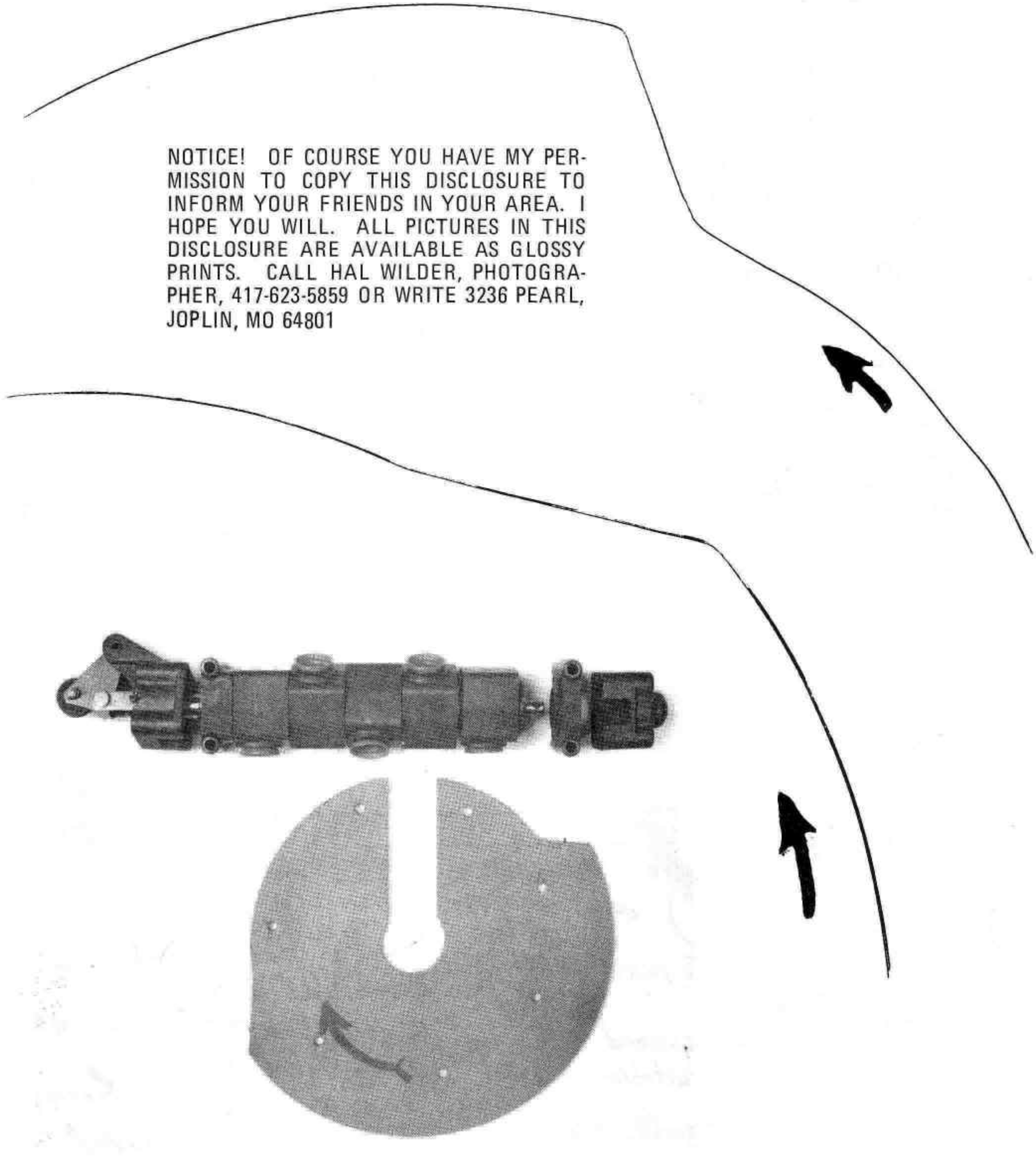
Phenolic-wood
or other suitable material



a — 1" shaft steel
B — ¼"x1" steel
c — pillow Block Bearings Bronze
d — Valve (12) or (24)
e — Pig Valve (15) Actuating cams
f — Valve spring loaded in this direction
g — car frame
h — 5/16" Dia Rod 3" long welded to shaft (a). h slides on frame (g) preventing (a) from Rotating

Omit cams (e) from Cam (8) for Number 2 Cylinder timing
Rig Pig Valve (15) to vent air During the center 4" of each cylinder stroke. Then adjust From there.
Use double acting rear pivit actuating cylinders.
Cyl Bore 1-2½" 2-4" Stroke 8"

Dimensions of this cam are; High cam 11" dia. Low cam 9" dia. Stop collar is designed to prevent wheel from rolling on low portion of cam.



NOTICE! OF COURSE YOU HAVE MY PERMISSION TO COPY THIS DISCLOSURE TO INFORM YOUR FRIENDS IN YOUR AREA. I HOPE YOU WILL. ALL PICTURES IN THIS DISCLOSURE ARE AVAILABLE AS GLOSSY PRINTS. CALL HAL WILDER, PHOTOGRAPHER, 417-623-5859 OR WRITE 3236 PEARL, JOPLIN, MO 64801

Most spool valve ports can be clocked (rotated in 90 ° incruments. Helps in keeping air hoses short.

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AIR CAR INVENTION PUBLIC DISCLOSURE
BY INVENTOR TERRY R. MILLER
CRESTLINE, KANSAS 66728 USA 1979

I hereby on Friday, Oct. 5th make a public disclosure of a air powered car of which I consider certain features are of such novelty as to warrent the granting of a U.S. Patent.

I hereby give my permission to anyone wishing to build their own air car. To the news media please copy and distribute this knowledge to anyone in any country. In making this knowledge public. I am foregoing any foreign patents.

Countries with three dollar gasoline are in need of this information. I invite engineers from all countries to drive Air Car One and take what you learn back to your home land.

I am seeking a U.S. Patent for a very good reason. To have some control over standardization and safety. I seek a modest sum of $10.00 per unit from commercial car builders. In return I shall help promote air cars and give of my knowledge to those building air cars for private use or for profit.

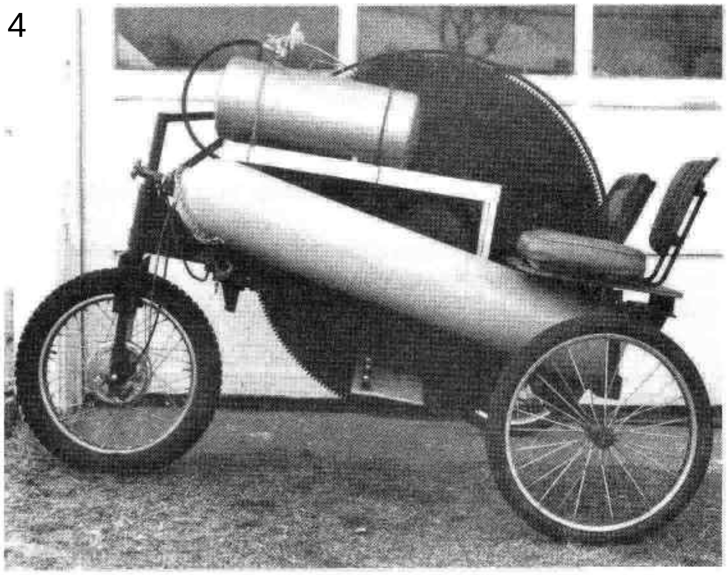
My first car (air car one) was put to practice July 19th, 1979 with one actuating cylinder providing motive power. It was driven many times a distance of 6.3 miles on a container holding 300 cubic feet of compressed air (gas). It takes 5 H.P. to fill a container with 300 cu. ft. of air. A 20 H.P. 4 stage compressor requires only a fraction more than 2kw hours of electricity for this task. At the current rate for electricity which is 5 cents per kw hour it takes 10.5 cents to fill such a container. A compressor running 12 hr. per day would qualify for lower rates as days passed in the billing month. WINDMILLS RUN COMPRESSORS.

My first air car was improved with the additon of a second actuating cylinder plus a new manifold (16)with it's related valves and hardware. It was first driven Aug. 19th, 1979 with satisfactory results. Manifold (16) is described in the disclosure.

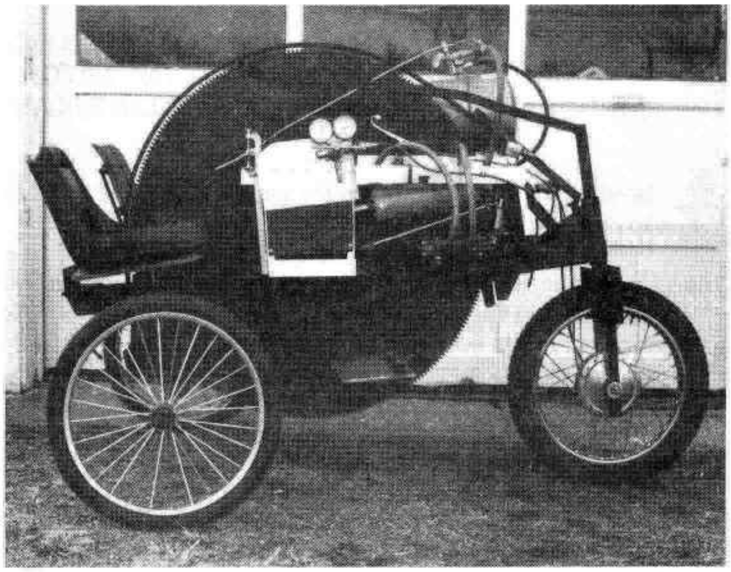
YOU CAN BUILD AN AIR CAR

My air car one was built as simple as possible. The air system consists of standard over the counter purchase items though some may have to be ordered. A list with numbers, function in the system and how to obtain follows:

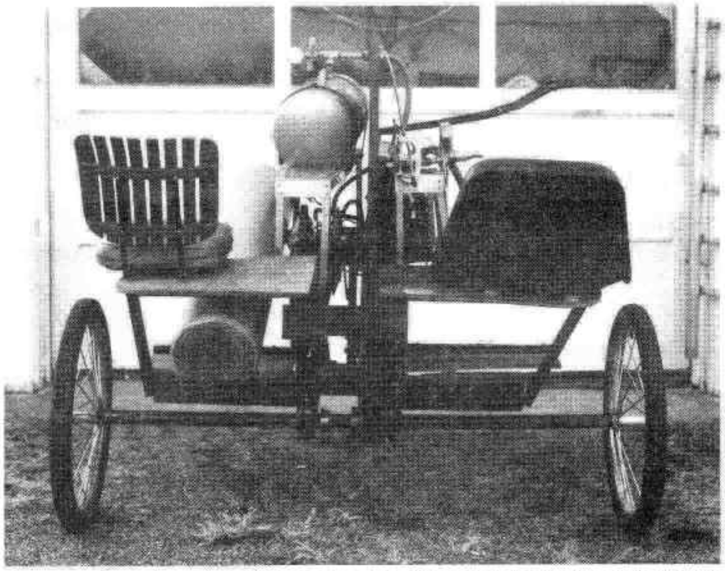
1. MAIN DRIVE GEAR - 6 diametral pitch 14½° pressure angle. Rack gear type tooth shapes. 270 teeth 3/16" face. Outside dia. 45 5/16" teeth. You can cut with jig saw or punch press. Tooth pattern avail. bearing supplies store. Gear now being manufactured call 316-389-2299.
2. AXLE GEAR - 6 pitch 14½° pressure angle pitch dia. 4" 24 tooth 1" or 1½ face. Avail. bearing supply.
3. CRANK SHAFT - 1½" stress - proof shaft grade steel. Avail. machine shop.
4. CRANKS - 8 ¾" dia. x 5/8" mild steel - 1½" dia. shaft hole. Center of crank pin or ball joint stud locates 3 7/8" from center of cranks. Avail. machine shop.
5. HUB - mild steel - welds to crank shaft - drive gear (1) bolts to hub (5).
6. BEARING LOCATIONS - bearing type options are; bronze sleeve - ball pillow block or flange mount, avail. bearing supply.
7. CRANK - PIN or BALL JOINT - if crank pin is used pin should be at least ¾" dia. - press fit to cranks (4) and welded. A clevis will be needed to attach cyl. rod to crank pin (7). Press fit bronze bearings in clevis so bearing rotates on crank pin (7) avail. machine shop. BALLJOINTS are avail. with thread sizes to match male threads of actuating cylinder rod ends. Avail. bearing supply. Crank (4) is threaded to accept male end of ball joint.
8. AIR VALVE TIMING CAMS -
   NOTE! In production (4) and (8) can be one (dual function)part. Also (4) and (8e) one part.
9. AIR CYLINDER - (gas tank) may be leased from welding supplies dealers. Can be purchased from ads in scuba diving magazines. From dealers who supply tanks to fire departments. From cylinder mfg. ask your nearest welding supply.
10. PRESSURE REGULATOR - Avail. welding supply. Reduces tank press to lower working pressure.
11. ON - OFF VALVE - Should be 3-way valve to vent down steam air to atmosphere when in off position.
12. TIMING VALVE - For number one cylinder. A four-way spool valve with tapped exhaust ports - with ¼" pipe fittings - with closed center position - cam operated - with return spring. Avail. industrial supplies or larger bearing supply. Function of valve (12) is to control the flow of air to and from the actuating cylinder number 1. Use hose ¼" I.D. avail. auto parts stores. Hoses were omitted from drawings for clarity, but show in pictures.
13. CAM FOLLOWER WHEEL - Function to roll onto cam (e) causing bell crank (14) to pivit, actuating lever of pig valve (15) which in turn vents exhaust air from cylinder one to the atmosphere when actuated. Avail. hobby shop. A model airplane tail wheel.
14. BELL CRANK or LEVER ARM - A simple device to actuate valve (15) exact shape will be determined by the location of other parts of air system.
15. PIG VALVE - On car No. 1, that is exactly what is used. It is an automatic pig drinking valve modified to operate as a lever operated vent to the atmosphere. Avail. farm supply store. Valve (15) is a lever operated non-pressure sensitive relief valve.
16. IS A MANIFOLD - Of which I claim as new and among other features of my car is of such novelty as to have not been shown by prior art. It's name is the Pressure Equalization Transfer - midstroke venting - pumped pressure transfer manifold. The name also describes its function. It allows use of two or more cylinders not operating in unison (as in a compound steam engine) but with different degrees of crank pin location even different stroke lengths to re-use air efficiently. Manifold (16) working in conjunction with various valves connected to it, allows the use of air at 450 P.S.I. in one cylinder re-use in another - then re-use in another and so on as many as six times before press is to low to be usefull as motive power. The manifold shown as (16) is needed for each cylinder starting with the first but, is not needed on the last cylinder, unless you wish to save final exhaust air for brakes, wipers, steering, horn, air driven electric generator etc.



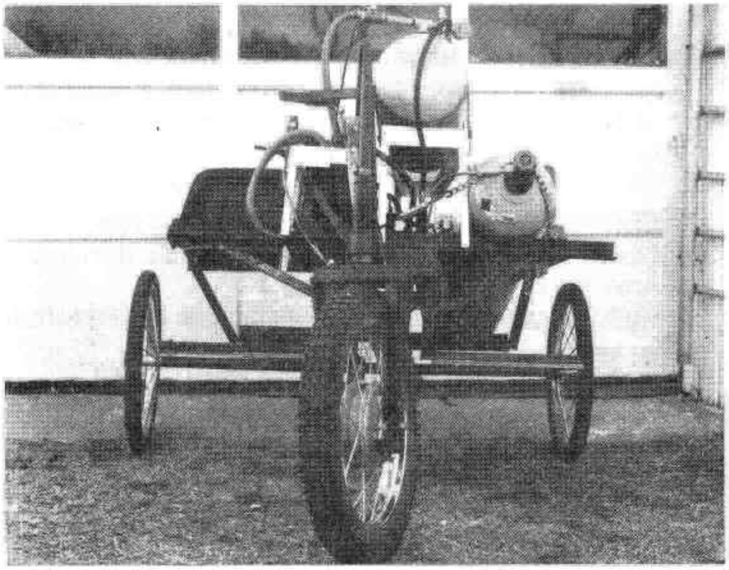
Air (gas) tank pictured (9) is a "T" size cylinder. Cylinder holds 2,250 lbs. pressure. Dia. is 9 5/8" length 56" - Wt. 145 lbs. Aluminum cylinders are available. Some small scuba tanks of steel or aluminum are lated at 5,000 P.S.I. Air cylinders are available in lengths up to 40 feet. Tank above (19) is a portable type commonly used for inflating tires.



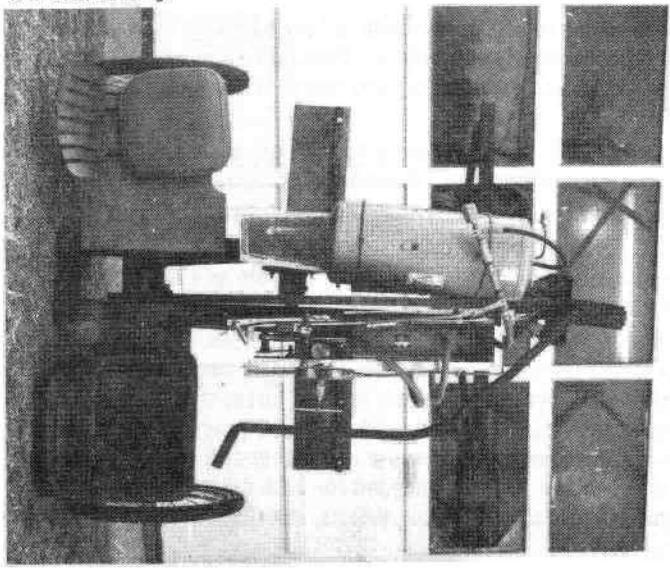
Most prominent is large black circular gear (1). The white structure in center of gear is aluminum angle pop riveted together to form a guard for drivers protection. Items on this frame from left to right are C-clamp, regulator (10) motorcycle brake lever, two air hoses looping over aluminum frame connecting actuating cylinder #2 to timing valve (24), air hose connecting valve (22) and timing valve (24) and the speedometer.



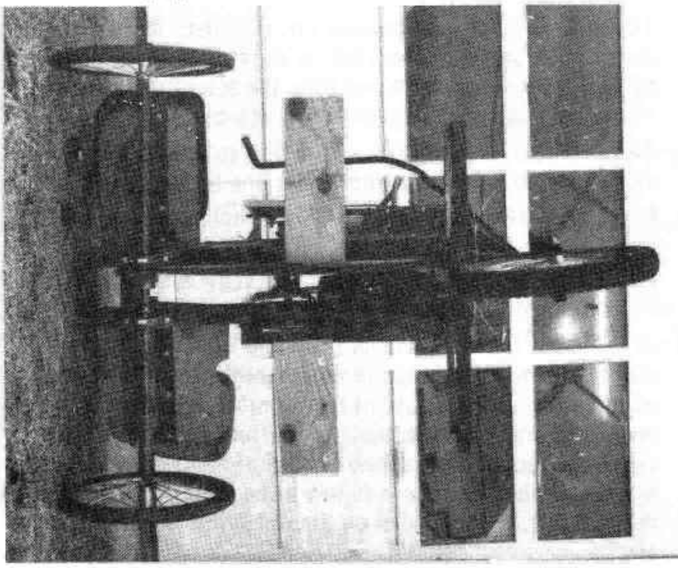
It was not my intention that a car would develop from the 8 ft. long bench. I set this frame up in the shop with the large gear and one actuating cylinder to see if I could develop an engine. The evolution that turned this work bench into the frame for a car was caused by my haste to see if this would go down the road. Just a work bench (test bench) in the beginning. I am not an automobile designer which is evident. Improvements over this vehicle are forth coming.



Pressure tank (19) shows on top of its aluminum support frame left of main drive gear (1) note the (Christmas tree) consisting of a pressure guage visible to the driver plus a relief valve (21). ½" pipe extends from (Christmas tree) to hold #2 actuating cylinder on-off valve (22). The four vertical items shown near tank (19) left to right air hose, steel rod from valve (22) to drivers reach, steel guard for main gear (1) and air hose connecting tank (19) to check valve (17).



See pressure guage just to the left of pressure regulator (10). Below the guage is #1 actuating cylinder on-off valve (11). It is a spool type - lever operated three way valve - with ⅛" tapped exhaust ports. Guage shows driver air pressure to #1 actuating cylinder.



Axle is 1½" dia. stress proof steel. Bearings are pillow block type. Note axle gear (2) between pillow blocks. One wheel welded to axle the other allowed to free wheel on axle.

17. **CHECK VALVE** - ¼" pipe thread avail. bearing supply. Valve (17) allows air flow from manifold (16) in one direction only into transfer hose (18).
18. **TRANSFER HOSE** - Use ¼" I.D. hose if length is less than 3 feet. Use 3/8" I.D. if over 3 feet.
19. **PRESSURE TANK** - Supplies air for actuating cylinder 2. Tank (19) obtains it's air from cylinder 1 exhaust through manifold (16) check valve (17) and hose (18).
20. **PRESSURE GUAGE** - 250 P.S.I. dial face.
21. **PRESSURE RELIEF** - valve set above desired pressure but below tank rated pressure.
22. **CYLINDER 2 ON-OFF VALVE** - Telflon seal (ball) valve ½" pipe threads. Avail. farm supply or larger hardwares. Valve (11) and (22) can be ganged or linked together to operate with the same lever.
23. **PRESSURE HOSE** - Use ½" I.D.
24. **TIMING VALVE** - For number 2 cylinder. Valve should have ½" pipe thread ports. Otherwise it is an identical valve to valve (12).

In drawings, valve to cylinder hoses were omitted for clarity, but show in pictures.

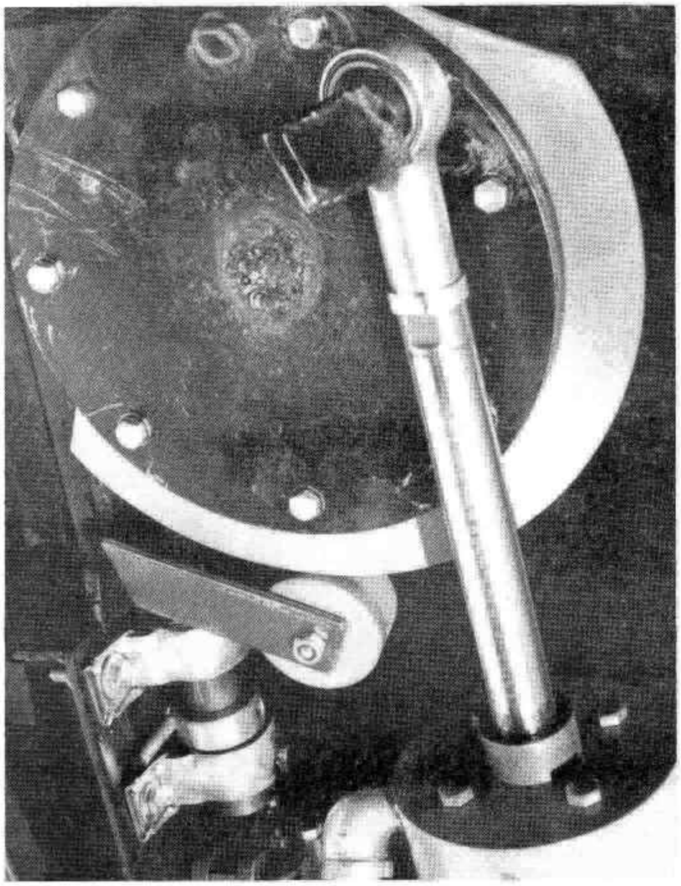
Double Acting Air Cylinders can be purchased from industrial supply houses and some bearing supply stores. Most air cylinders are rated 200 or 250 P.S.I. If you actually expect that much in the cylinder you will have to set Reg. (10) to 260 if you want 250. A cylinder rated less than 250 would be a looser unless you used smaller wheels - changed gear ratio or changed stroke and throw - we used 24" dia. bicycle size tires, filled with urethane foam rubber. They are welded spoke poney cart wheels. Motorcycle wheels work with modifications. Our air car 1 uses a motorcycle front wheel with brake. Naturally, car weight should be kept as low as practical. During the invention and construction of air car 1, I obtained the first and most quickly avail. materials. Truthfully, we do not know which name brand of cylinders, valves etc. will be the best by our standards. However, we will supply a list of major component parts with mfg. names, prices paid etc. on request. This would be from air car 1.

I urge all valve, cylinder, tank, wheel, and other manufacturers who can make or wish to supply component parts to get a catalog to me so, I can compile a list of suppliers wishing to stock parts for the public to purchase or for air car mfg. I also urge prospective air car manufacturers to get in touch with me. Building your own air car is the first step toward manufacturing.

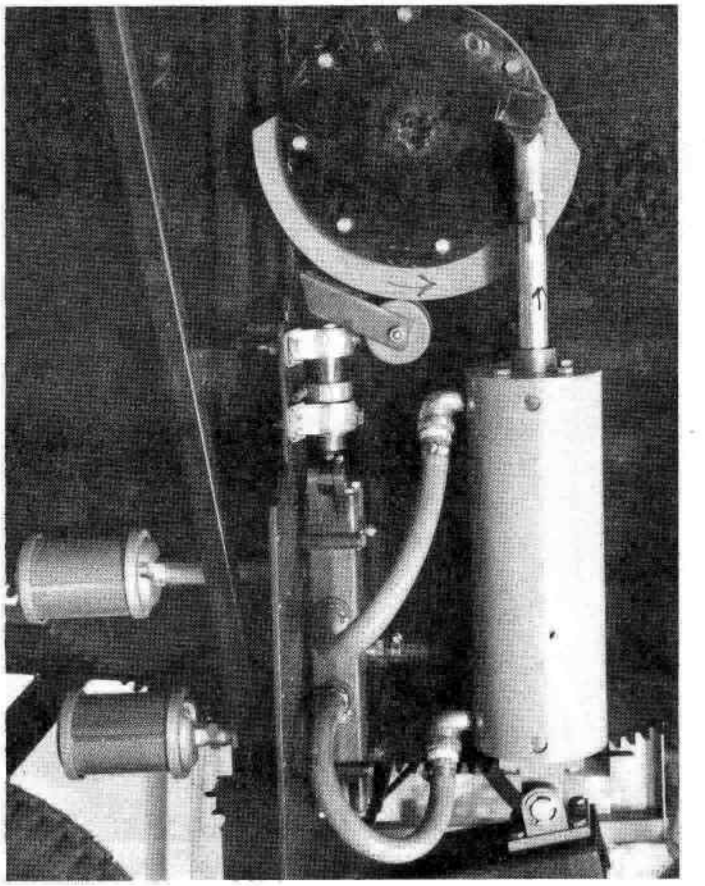
If you have a machine shop with punch press and metal bending facility near by, you can get to manufacturing air cars soon.

I want to thank those people who have helped in putting air car 1 together.

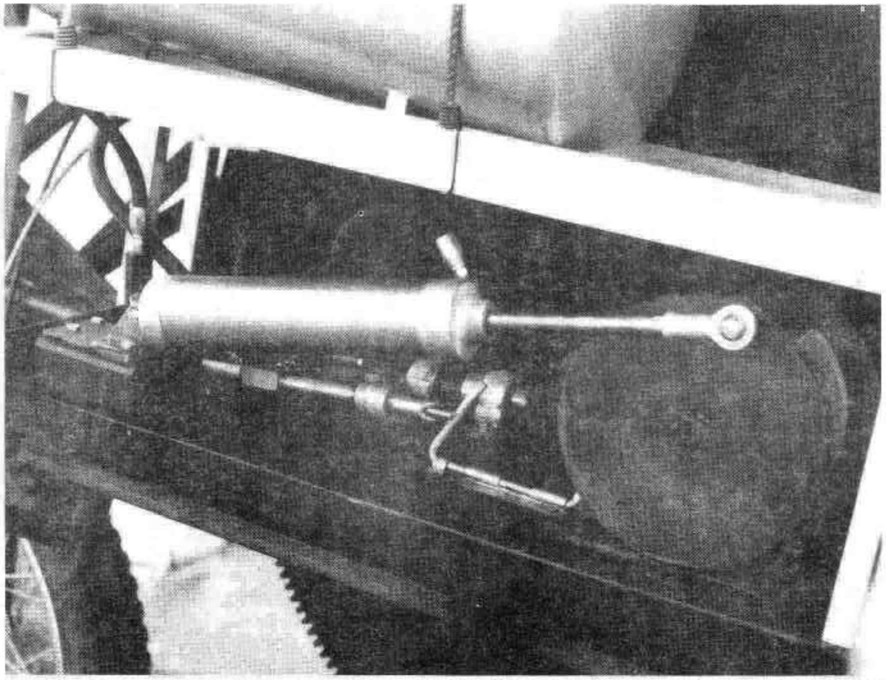
More information is available or my personal help by contacting Terry Miller - 316-389-2299 - Box 80 Crestline, Kansas 66728.



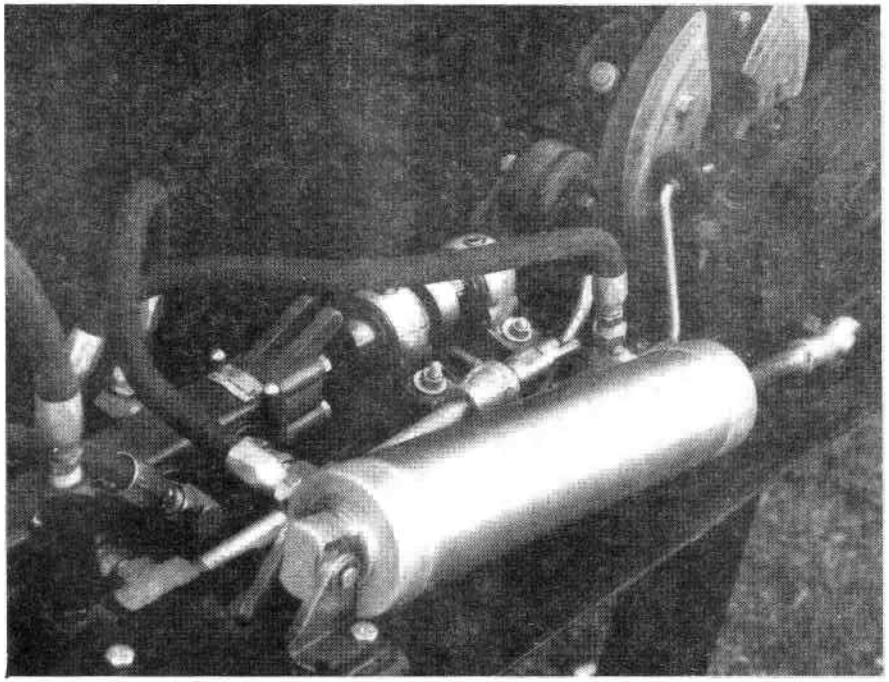
Spaced ¼" holes drilled in crank (4) for installing cam (8). Skate-wheel and axle purchased from rink.



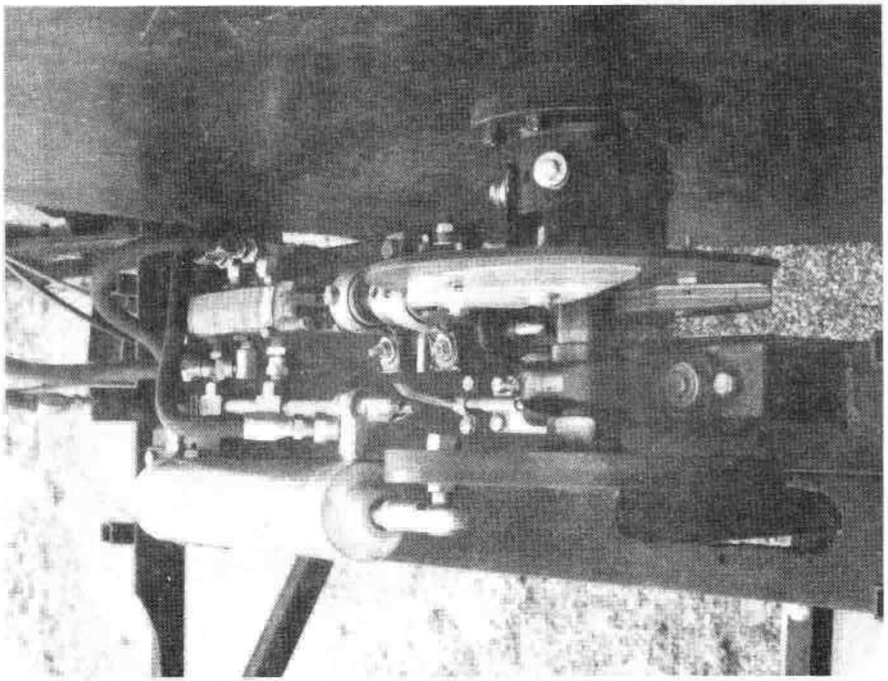
Number 2 actuating cylinder with cam timing. Short hoses mean less air used per stroke. Mufflers are almost to quiet. Cam bolted to crank (4). Evolution toward one part.



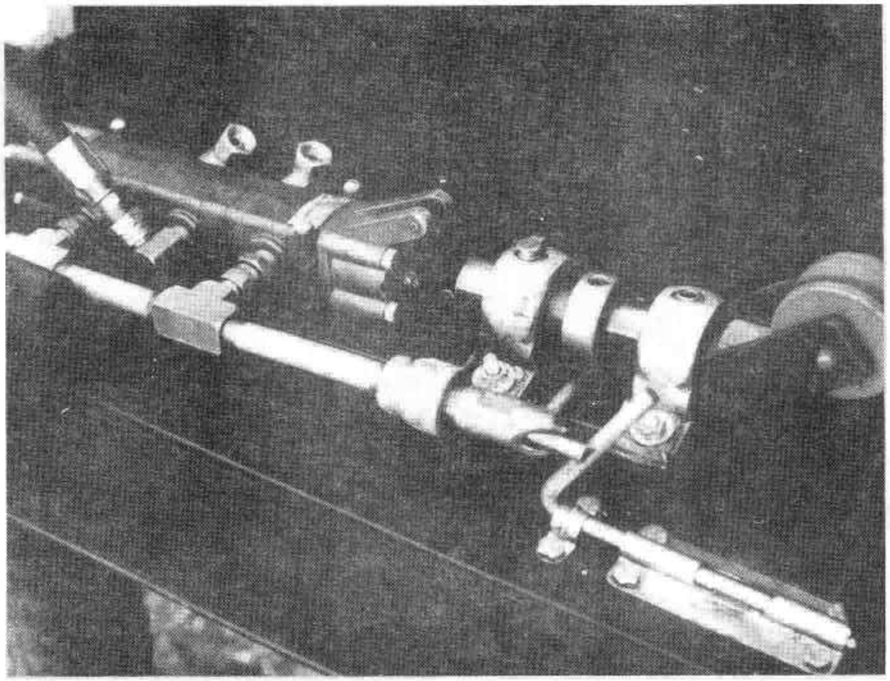
Picture shows rear pivit pin of actuating cylinder #1 had to be elevated from work bench frame to allow cylinder to pivit. Pillow block bearings were thought to be the easiest way to set up an air engine, however, they lead to other design problems. I would suggest that when you build your car you use flange mount type bearings which will allow for better alignment and distribution of force while minimizing frame twisting.



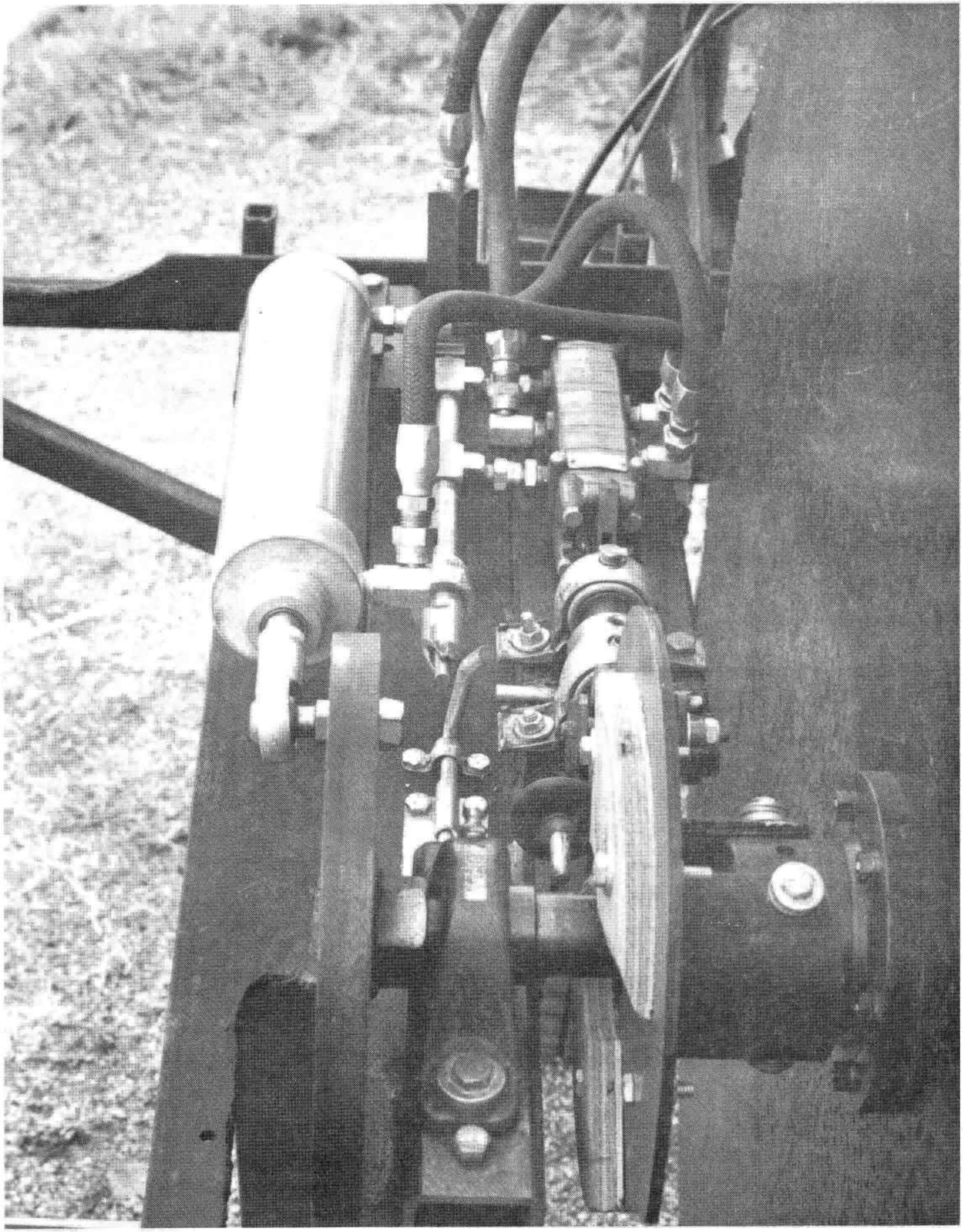
Check valve (17) is the darkest object in the lower left hand corner of this picture. Check valve (17) shows in picture above, behind pivit pin of actuating cylinder.

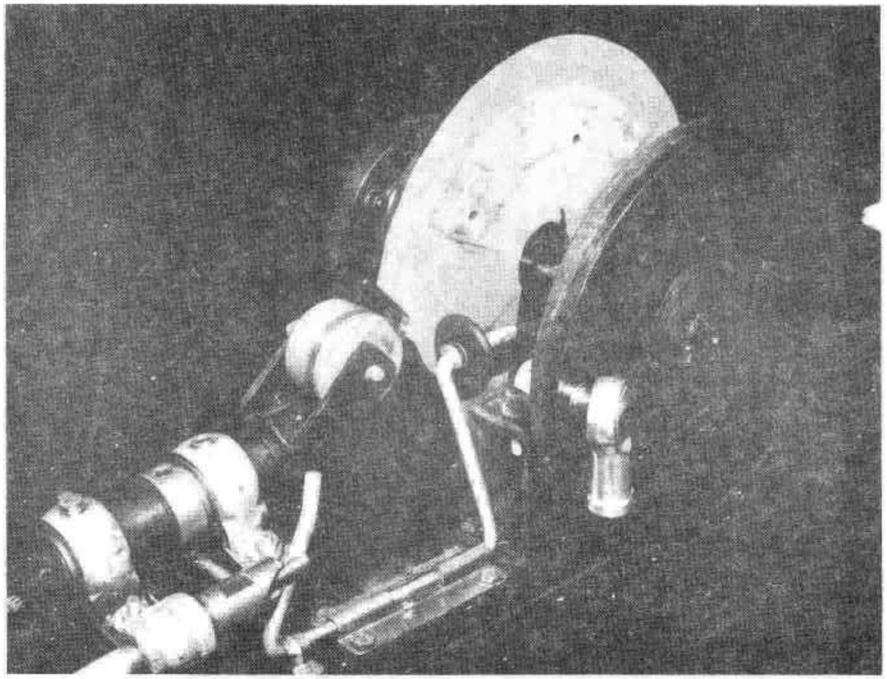


Picture shows complete air system layout for #1 actuating cylinder. Once the air in this system clears check valve (17) it becomes a part of the air system for # 2 cylinder. This transfer of air from one system to another can be done six times. Note pillow block bearing elevated from the work bench angle iron using a section of 2" x 3" box beam. With a force of 1250 lbs. exerted the car frame twists slightly.



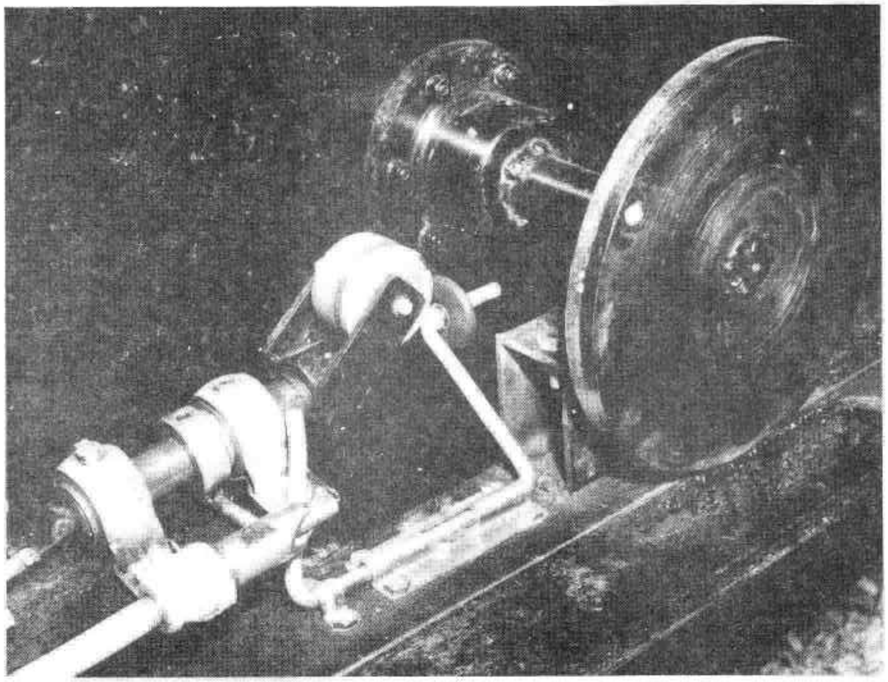
View of major portion of manifold (16) including pig valve (vent valve) which is operated by bell crank (14). Note hoses are removed from fittings of timing valve (12). Suggest drilling hole in shaft (a) for set screw of stop collar.



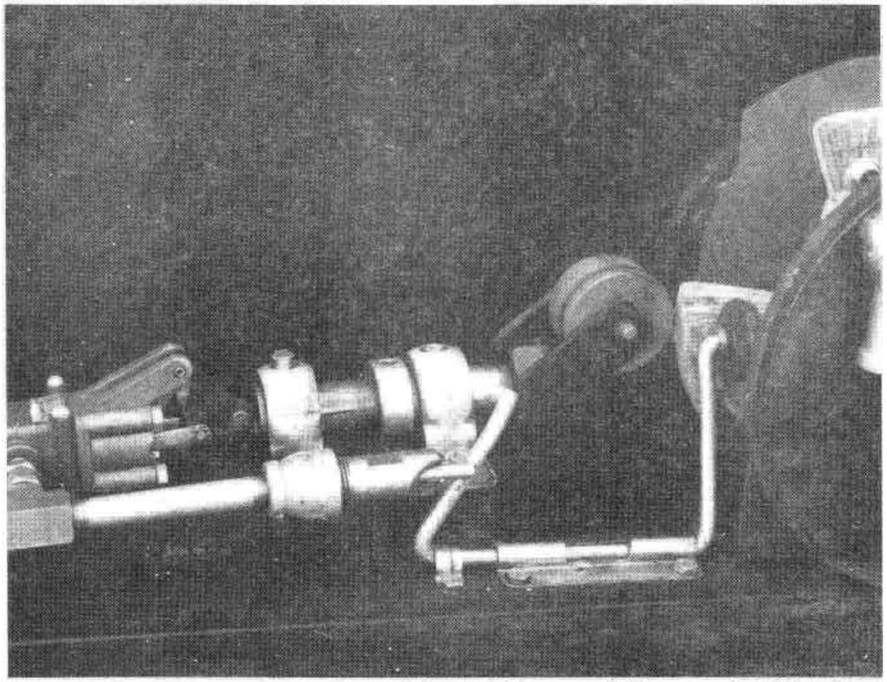


Picture shows plywood cams (e) removed from Cam 8. Ball joint (7) dangles. Number 1 actuating cylinder is removed by pulling pivit pin and unscrewing rod end out of female threads of ball joint (7).

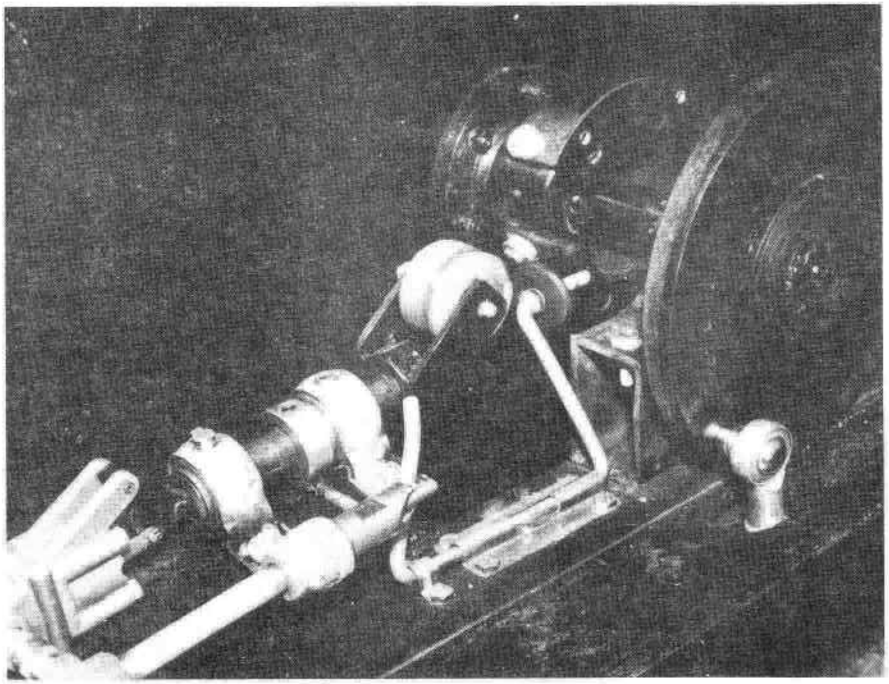
Lower parts in picture below L. to R. are ½" brass "T", ½" pipe nipple, ¾" to ½" bell reducer, pig drinking valve (15), 5/16" bell crank (14), door bolt bracket and (13).



Picture shows hub (5) exposed to view. Cap screws (heat treated bolts) are suggested for gear to hub attachment. ¼" - 18 cap screws shown. Crank shows threaded hole as ball joint (7) is removed in this picture.



In the picture the upper parts shown left to right are as follows: valve (12), pillow block (c), shaft (a), set collar stop, pillow block (c), shaft (a), steel (B), skate wheel and timing cam.



I drilled and tapped hub (5) ¼" - 18 (in three places) to provide for attaching a slotted (spool shaped) metal part to which I then bolted timing cam (8) and the two pig valve cams (e).

OPERATION STUDY TEXT
Air Powered Vehicle

STUDY DRAWING 9
(back side)

In operation air flows from tank (9) through it's facuet type valve and through a manifold to regulator (10). In flowing through regulator (10) air becomes regulated as to the desired pressure selected by the driver. Of two guages on regulator (10) one shows tank pressure, one regulated pressure. This regulated pressure should not be allowed to exceed the rated pressure capacity of number 1 actuating cylinder, or parts (11), (12) and hoses connecting them. (A SAFETY RELIEF VALVE MUST BE INSTALLED BETWEEN REGULATOR (10) AND VALVE (11). SEE AIR SAFETY TEXT). Air (at regulated pressure) flows through valve (11) to timing valve (12).

Two hoses (not shown) connect valve (12) to actuating cylinder number 1. With air pressure applied to one port of an actuating cylinder the cylinder piston is made to operate (move).

At any given time in operation one of the two air hoses is supplying a path for regulated air pressure to move the cylinder piston. At the same time the other hose is providing a path for exhaust air or air that has already been used against the piston to provide motive power. Both hoses never supply motive air pressure to the actuating cylinder at the same time. Both hoses never carry exhaust air at the same time. Each hose connecting a port of the actuating cylinder to a port of it's timing valve is either providing a path for regulated (motive air pressure) or a path for exhaust air pressure. Note! I said exhaust air pressure. Just because the air has done work and pushed a piston to one end of a cylinder does not mean we have to release it back to the atmosphere right then and there.

Let's study! There has got to be a way to save this air. Look at the Air System layout drawing. Find cylinder no. 1 next to tank (9). Note that the piston is shown at one end of the cylinder nearest the pivit pin. Also, the piston rod is pulled all the way back. Since the rod end of cylinder no. 1 is screwed into ball-joint (7) or crank pin (7) it has also pulled (7) as far back as it will go. This has rotated (turned) crank (4) to a position commonly called (dead center). Now, locate valve (12). Remember the two hoses not shown in drawing? It is at this point in crank rotation (dead center) that valve (12) must act to change the duties being performed by the two hoses from pressure to exhaust the other from exhaust to pressure. Alternate pressure - exhaust - press - exhaust - controlled by valve (12) times the actuating cylinder to push, then pull, push, then pull.

Actuating cylinders that are designed to provide travel and force in both directions are called double-acting cylinders. In operation air flows in both directions between valve (12) and cylinder no. 1 Air flows in both directions in each of both hoses.

Now, let's set up a situation to study air pressure. Regulator (10) set to deliver air at 210 P.S.I. the car is rolling down the road. Locate cylinder no. 1 in the air system layout. Now let's stop the car. No more movement. Wheels stopped. Crank rotation stopped. Actuating cylinder no. 1 stopped in the position shown. The inside of cylinder no. 1 between the piston and rod end of cylinder is filled with air under pressure at 200 P.S.I. Remember!all action is! stopped!. Let's see what we have. We have an air tank (pressure tank) containing about 39 cubic inches of air. Not, just atmospheric pressure air but, air compressed to a pressure of 200 P.S.I. The action is still stopped! We have this small air tank which is (number 1 cylinder). Let's go about recovering the exhaust air or the air about to be exhausted when we let the action continue. Then we can find out the problems we will encounter and how to solve them. All air leaving cylinder no. 1 has to flow through valve (12) and out the exhaust ports of valve (12) these exhaust ports are tapped (threaded to accept pipe fittings). Draw two light pencil lines from valve (12) to pressure tank (19). Let these lines represent an air hose, a short cut if you will. Just, forget for now that there are other parts numbers 13-14-15-16-17 and 18 in the drawing. We now allow the car to start rolling down the road. As soon as crank (4) rotates, cam (8) on the same shaft also rotates, actuating valve (12). Instantly! the pressure hose becomes an exhaust hose and the exhaust hose becomes a pressure hose. Exhaust air rushes from cylinder no. 1 which during the stop action was a small pressure tank. It flows through one hose to and through valve (12). The air exits valve (12) through one exhaust port. Air then enters our pencil lines (short cut hose) and flows directly into tank (19). If a "Y" fitting were fitted to valve (12) at it's exhaust ports and connected to our pencil lines hose, each subsequent exhaust stroke of cylinder no. 1 would send a blast of exhaust air through this/hose and into tank (19). Because, each stroke of cylinder no. 1 is both a power and exhaust stroke combined. With each exhaust of air going through valve (12) and to tank (19) here is what would happen. Pressure increases are just examples; First stroke; tank guage pressure goes up to 4 lbs., next stroke 8 lbs.,next stroke 13 lbs., next stroke 15 lbs., next stroke 19 lbs., and so on up to 200 P.S.I.

The transfer of air from cylinder no. 1 to tank (19) is governed by basic fluid laws. The equalization of pressure causes air to flow. With tank (19) pressure 10/P.S.I. it is easy to see that the pressure difference of 190 P.S.I. will cause pressure equalization to be swift and air flow fast.

With this direct method of air transfer through our (pencil lines) hose we find that when tank (19) pressure reaches say/100 P.S.I. and after pressure equalization has taken place, cylinder no. 1 has problems. Cylinder no. 1 finds it cannot deliver full force to the ball joint (7). With 200 P.S.I. on one side of the piston and 100 P.S.I. on the other side of the piston, we discover that fluid laws work both for and against this direct method of transfer. The same law of equalization of pressure is robbing cylinder no. 1 of half it's power potential.

Can we use the direct method of air tansfer to tank (19)? Yes, but with limitations. Should we have a use for air at 10 P.S.I., air could be drawn from tank (19) at a rate fast enough to keep tank (19) pressure at 10 P.S.I.. Back pressure would be slight and transfer swift and fast. When tank (19) pressure reaches 30 P.S.I. we begin to pay a penalty in lost power. Compound steam engines transfer superheated steam from one cylinder to another larger cylinder via the very direct method. Such steam continually expanding as it is ported to another larger cylinder can perform it's job with little back pressure problems due to the nature of steam. Air is a different ball game. Air does not have this continually expanding nature of steam. Air does have the capability of being transferred by equalization of pressure. Pressure equalization transfer is fast, but, not super fast. As the pressure difference between cylinder exhaust and tank pressure grows less, pressure equalization slows down.

It stands to reason that if we want to use air from tank (19) to actuate cylinder no. 2 we want as much pressure and air volume as possible without hurting the performance of cylinder no. 1 Two strokes per second push and pull are within the capability of an actuating cylinder. Once a cylinder reaches a certain speed of actuation while doing work (not running free with no load) a point of non-productivity is reached at which the increase of air pressure will not increase the power or speed of the cylinder. This phenomenon is as I see it by my tests is due to the fact that increasing pressure to a cylinder also increases the volume in cubic inches of air being forced into the cylinder and also the volume of air exhausting from it. A point is reached where the cylinder just cannot vent and port this much air volume.

Now, about all those other parts, (13) thru (18). A study of the pictures should help to identify these parts and understand how they help air car 1 handle air transfer. Manifold (16) is the pressure equalization transfer-midstroke/venting - pumped pressure transfer manifold.

Pressure equalization transfer. Exhaust air flows from valve (12) into manifold (16) toward the lower pressure of tank (19). This pressure equalization takes place during the first 2 inches of stroke (push or pull) of cylinder no. 1 after reaching dead center. Valve (15) is closed during this portion of cylinder stroke so, the air has no other place to go during pressure equalization except into tank (19). Once air passes check valve (17) it is isolated from cylinder number 1 air system and does not return. There is no mechanical force or leverage used for this portion of air transfer.

Midstroke venting is the venting of a small portion of the exhaust air remaining inside cylinder no. 1 and in the manifold (16) at the beginning and during the center 4 inches or center half of both push and pull strokes. An actuating cylinder is capable of delivering equal force at it's rod end during the entire length of stroke but, force and torque are two different things.

As an example; 1,000 lbs. of force delivered to a crank pin that is on dead center is useless in producing torque. When crank pin has rotated to a point 2 inches to either side of an imaginary line between the center lines of the pivit pin and crank shaft 2,000 inch lbs. torque is produced. With crank pin 4 inches either side of this line a torque of 4,000 inch lbs. is produced. This midstroke 4 inches of cylinder stroke is the portion capable of providing the most power to the wheels of the car.

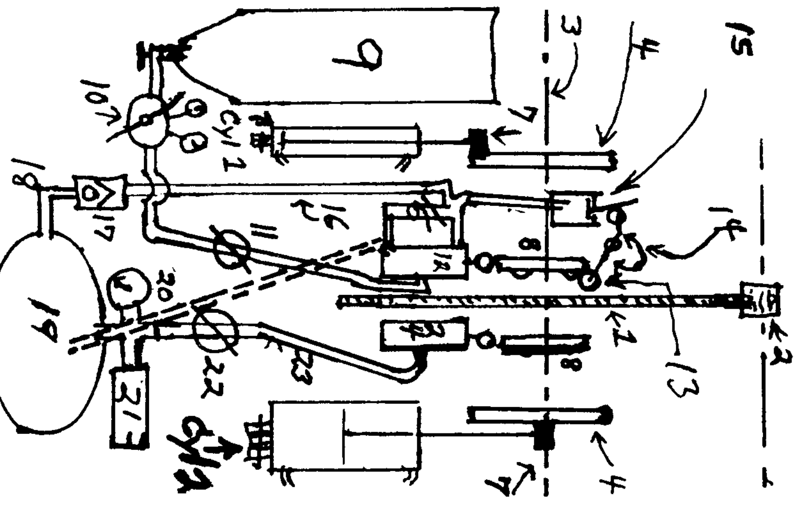
Midstroke venting of some exhaust air to the atmosphere to relieve back pressure during this critical portion of each power stroke is done as follows. Valve (15) opens venting air to atmosphere. Check valve (17) prevents air from tank (19) entering manifold (16). Cylinder no. 1 is allowed to operate without any significant back pressure from tank (19).

Pumped pressure transfer During the last 2 inches of each stroke (push and pull) valve (15) will be closed. The actuating cylinder then acts as a piston pump upon the remaining exhaust air inside the cylinder and pumps this air into tank (19) through manifold (16) check valve (17) and hose (18). This pumping action does not diminish the torque at the crank shaft. Cylinder no. 2 is near 90° or max. torque portion of it's stroke. The sheer leverage available to drive cylinder no. 1 to pump air to tank (19) during this last 2 inches of stroke is many, many times that required for this task. Also, there is regulated pressure on the power stroke side of the piston of cylinder no. 1 during this pumping action. It's not helping much but it's there none the less.

The pictures and other words on parts and their function in the system will help clairify the pig valve (15) and how it is actuated in midstroke. Should you purchase a pig drinking valve get the high pressure one and drill out the flow metering orafice or jet as large as possible for max. air flow. A 2 way spool valve (cam operated) can be rigged to do the job as valve (15) instead of a drinking valve. A valve type like 12 and 24 except just a two way valve.

Cylinder number two is next in line to use the same air already used once in cylinder no. 1. Note! in drawing cylinder no. 2 is in midstroke position. Crank pin or ball joint (7) is at 90° or max. torque position compaired to cylinder no. 1 which is at dead center stroke position. After the study of the air system for cylinder no. 1, cylinder no. 2 system looks simple. It is and does not require much extra learning.

Words of caution! are in order regarding safety! It seems that car builders are inclined to drive car on cylinder no. 1 while at the same time adjusting valve timing and seeing and learning how exhaust air is saved. This is good for learning. It's logical to drive car with valve (15) operating and also inoperative, to observe effects of back pressure for your self. Be sure for safety to set relief valve (21) to relieve pressure well below rated tank pressure. Have guage on tank visible to driver for observation. Also, a guage on ONE inlet port of cylinder no. 1 and the inlet side of valve (11) are helpfull in observing visually what the air is doing. **Driving and building your own air powered car is fun. A once in a lifetime experience. Experience is the key word, because, I cannot convey my experience to you totally. By watching the guages you can learn what I learned and how I learned it.**



Dotted lines ---- Represent short cut hose in study text.

AIR SAFETY

The force of wind in nature does work for man and also causes destruction and deaths. Wind the movement of air caused to flow due to differences in pressures. Man made structures not only have to be built to stand up to do a job but, also to resist the forces of nature including the force of the wind. A safety factor must be built into a tall building to give it strength to resist the force of natures wind plus a safe margin above and beyond the wind forces ever encountered at the buildings site in the past. Because of miscalculations bridges, buildings, towers, ships or other man made structures often are taken by the force of wind. Natures wind, uncontrolable by man and still often unpredictable. The compression and storage of inert gases and use by man is controlable and predictable. Taking air or other inert gases from nature and storing it in special cylinders under compression in a reduced volume has been common practice primarily in the welding supply trade for over half a century. Safety regulations covering the storage, transportation, and intra-state commerce of compressed gases have also been in effect for over half a century. Storage cylinders have been manufactured since the turn of the century.

One reason the over all safety record for compressed gases has been good is because man can use basic fluid laws to understand and handle compressed gases. The safety record for compression and storage of inert gases is phenomenal. Compressed gas cylinders last for years and are tested regularly for safety. I have in my shop a cylinder that is 56 years old yet still certified by tests and looking as good as the newest cylinder available. It may have cost as little as $35.00 or less to manufacture in 1924, but it's worth $120.00 today.

Why? Is the safety record for compressed gases so very good? Firms dealing in compressed gases are always telling it like it is. Welding distributors display safety posters. Safety booklets are made available to individuals using or handling compressed gases. An industry more than a hundred years old. Many years ago steps were taken toward setting standards. The resulting industry standards for the manufacture of compressed gas handling hardware are honest. The danger of potential for disaster were and still are in the open. Potential Danger Delt With Openly. The terms; coverup, playing down hazards or profit oriented safety decisions were unthinkable years ago in setting these standards.

Man is capable of destroying himself while using many forms and varieties of energy; gasoline, the Atom, water, x-rays, explosives, micro-waves, natural gas, synthetic gas, compressed gases, coal, oil, etc. The use of some energies cause short and long term effects on health both good and bad, and man does not know what the actual effects will be.

Compressed air, the same air you breath, is an inert non-burning gas unlike pure oxygen, acetylene, natural gas and other gases that burn as fuel. I don't think any long term hazard exists in using compressed air (the same air we breath every day) in a pneumatic engine for motive power. The other dangers of using compressed air have been clearly known for over a century that compressed air has been used. Only in the last year has the use of compressed air become feasible, Economically and Politically. I figure it happened when gasoline hit 60 cents per gallon.

What is the danger of compressed air if it is inert? The danger is the probability of exploding actuating cylinders-valves, hoses, and other hardware if these items are allowed to receive compressed air at pressures above that which they are able (rated) to safely handle. All air components of an air car must be rated as to the maximum pressure they can handle. Air pressure exerts a force to stretch hoses and actuating cylinders just like a balloon. The walls of steel or aluminum storage tanks and actuating cylinders stretch as do the walls of rubber or plastic hoses giving slightly to the stretching force caused by air pressure. Manufacturers of air handling hardware supply literature stating the rated pressure maximums in pounds per square inch (P.S.I.) These ratings should not be exceeded. The exploding (like an over filled balloon) can occur if hardware is subjected to pressures above their rated capacity. The air does not blow up, ignite or burn if the wall of a cylinder is stretched beyond it's breaking point. It is the force of the air trying to and actually escaping to the outside (atmosphere) that can split a cylinder wide open when the elastic limit of it's wall is exceeded. It is the flying pieces that can kill.

Why then is the inventor of an air powered car who wishes to promote air powered cars telling of the danger connected with the improper use of air? I see it as the only right thing to do. Let's look at some essential trades. Welders have to have compressed gases. Much of the general industry has to have compressed gases. Hospitals have to have compressed gases. Utility companies have to have compressed gases to name a few. Several large companies supply gases to fill these essential needs. Competition between gas suppliers is a fact. However, it seems that the supplier who was the first to operate in a certain geographical area usually retrains the larger portion of the gas business trade. The point is that competition between gas suppliers has not been an important enough factor to effect safety standards. In thinking about it, it is very possible that because gas suppliers have not had to soft pedal the danger of compressed gases in order to sell them that this has been a major factor toward establishing an enviable safety record.

SAFETY DEVICES ARE ESSENTIAL

SAFETY DEVICES AND SAFETY MEASURES FOR COMPRESSED AIR POWERED CARS

A safety relief valve should be installed between pressure regulator (10) and on-off valve (11). Valve should be of an approved type and rated to relieve pressure at 15 P.S.I. above the rated pressure of number 1 actuating cylinder. Safety valve should be factory set, sealed and tamper-proof. Safety valve should have a flow minimum of 140 cubic feet per minute (140 c.f.m.) flow at relief pressure). All other hardware in the number 1 actuating cylinder air system should have a pressure rating equal to or above the rating of number 1 actuating cylinder.

A safety relief valve should be installed on every pressure tank (19) that is used. Valve should be of the factory preset or manually adjustable type. Valve should be set to relieve pressure in tank (19) at a pressure below the rated pressure of tank (19). Valve should also be set to relieve pressure in tank (19) at or below the rated pressure of the actuating cylinder being supplied by tank (19).

Don't install any parts of which pressure ratings are unknown or cannot be determined from standard engineering texts or manufacturers charts. Should you have questions regarding air safety call Terry Miller, Crestline, Kansas.

Do I have all the answers? No! But, I will do my best! to put you in touch with someone or some company that can answer your questions.

WHO SHOULD BUILD AN AIR CAR NOW

A copy of air car 1 is a good learning vehicle and parts are easy to obtain. Copies of air car 1 can carry a letter designation. The car completed January 1980 built by students at Buffalo, Oklahoma is air car 1A. The next car completed will be air car 1B. These first air cars will be more valuable than the cost of construction for several reasons.

Do you have some hand tools? Are you able to read the air car information and understand most of it? Do you have a place to work? Can you undertake a building project without disrupting your family life? Can you afford to spend say $2,000 over the next six months? Do you love to design and build? Would you get pleasure from holding a news conference to demonstrate your air car? Are you more than just casually interested in owning and driving an air car? Do you feel you are likely to come up with new design ideas which could bring factory production closer to reality? Would you like to manufacture air cars? Not just maybe? But, as soon as possible? If your answers are yes to most of these questions, I feel that you must get started now. If you feel it is something you just have to do, get in touch with me and I will help you as much as I can. Call Terry Miller 316-389-2299.

SHOULD YOU DECIDE TO BUILD AN AIR CAR

Should you decide to build an air car, get in touch with us in Crestline, before starting construction. As far as I know, I'm in contact with everyone building and driving air cars. It's just as though I had several cars under construction myself. New approaches to design and building are being used. This is super speeding the evolution process toward a production car suitable for town driving. Information and ideas are coming in daily from builders and non-builders alike. It's the air car builders that are first in line to be future manufacturers as far as myself and my family are concerned. They are learning and working to promote air cars. They are doing this unselfishly realizing the urgency of this endeavor. You are welcome to join with us all in any capacity to be an "AIR POWER ADVOCATE."

WHO SHOULD WAIT UNTIL A KIT IS AVAILABLE

Would you like to get around town in a car you assembled yourself? A car already designed but requiring assembly? Do you have some hand tools or friends with tools to help in assembly? Do you have a pretty good idea of how the car works after reading the information? Do you feel you could get others interested in forming an air car club with their own air station? Are you finding yourself telling all your friends about air cars? Do you feel an urge to locate the first designer builders in your state to see how they are doing? If your answers to most of these questions is yes, I feel you should consider placing an order with the designer builders in your state, or let them know you are interested in a kit. Also, you can do what you can to spread the word about air cars. You could write to Crestline, Kansas and we will let you know when a kit or car becomes available in your state.

WHO SHOULD WAIT UNTIL AIR CARS ARE TOTALLY MANUFACTURED

If your interest in air cars doesn't fit in the designer, builder or kit assembler catagory then maybe you are a prospective first air car buyer. What interests you most about air cars? The economy? Do you feel they will be fun to drive? Do you like the idea of energy savings? The quiet running? Easy maintenance? Do you like to try new things? New ideas? If your answer is yes to even one of these questions you may be the first to own a factory new air car in your area. Meanwhile please let it be known that you are interested in owning an air car. By telling your friends you may be instrumental in getting some one in your area interested in becoming a designer builder.

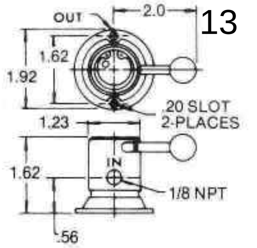
Air powered cars are here. Time till available for purchase, may be influenced how fast the information on how air cars function gets into the right hands. Would you like to own an air powered car? Write to Crestline, Kansas and we will let you know when they become available in your state.

MODEL 3MV8 ✓

3 Way Disc Air Valve operates single acting cylinders. Full 1/8″ orifice — 1/8″ NPT inlet and outlet ports. To operate, a precision lapped disc is rotated through 60° by means of a ball handle which will hold set position. To repair remove handle and retaining ring.

$16.85

BASE PRICE



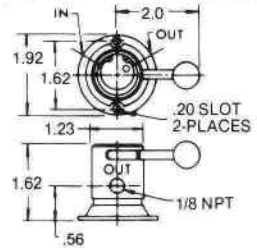
BIMBA MANUFACTURING COMPANY
MONEE, ILLINOIS 60449
312/534-8544 · TWX 910/651-1870

MODEL 4MV8 ✓

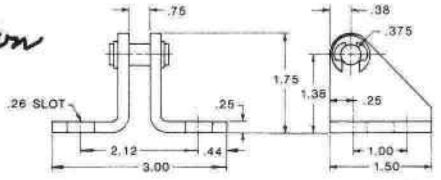
4 Way Disc Air Valve operates double acting cylinders. Ball handle will rotate through 120° and will hold set position — 1/8″ NPT ports are located 120° apart — orifice 1/8″ diameter. To repair remove handle and retaining ring.

$20.50

BASE PRICE



I used the two valves shown plus the DXP cylinder shown on Air Car 1, for a one cylinder car. A low cost air engine.



D-620
Pivot Brackets
$5.30

50□-DXP ✓

BIMBA
MONEE, IL

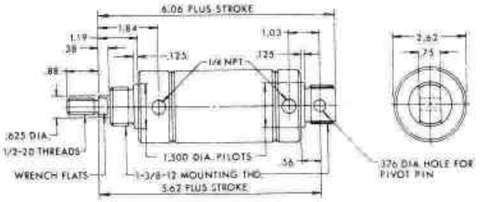
Double Acting - Universal Mounting Type - Pivot or Double End - Air Return - Bronze Rod Bushing and Bronze Pivot Bushing
Standard Stroke Lengths: 1″ increments to 6″, 8″, 10″, 12″
Maximum Stroke 32″
Stainless Steel Rod Standard

Optional Accessories:
✗ D-231-3 Piston Rod Clevis
✗ D-615-1 Foot Bracket, D-620 Pivot Brackets ✓
✗ D-2540 Mounting Nut

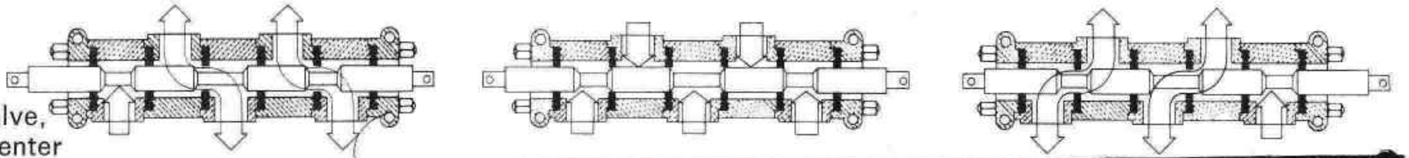
$43.20

BASE PRICE

Add $1.60 per inch of stroke



WABCO



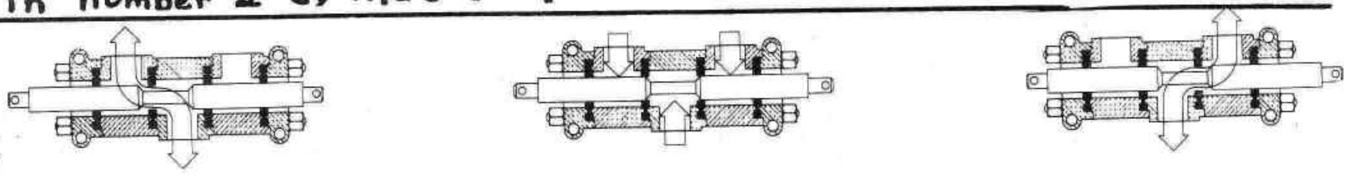
Four-way Valve,
Closed Center

PD2 = ¼″ Valve 83.10 List
PD4 = ½″ Valve 101.65 List

Two cylinder operation required replacing the 4-way disc valve with a 4-way spool valve, so exhaust air could be saved for re-use in number 2 cylinder.

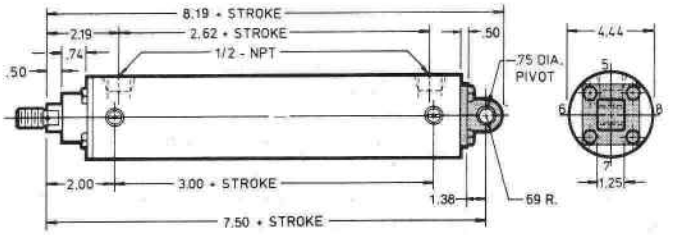
Most valves are made from common parts to simplify repair and stocking. No special tools are required to service or modify (Type "D" Pilotair Valves.) The valve operators, mounting bracket or any of the port segments may be rotated in 90° increments to fit most any installation problem.

$61.85
↓

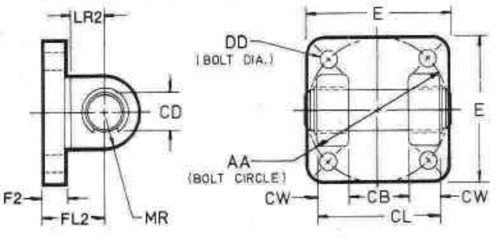


Three-way Valve,
Closed Center

PIVOT MOUNT **BASE PRICE $75.00**



MOUNTING KIT #MP-125 PRICE $10.00



CLEVIS BRACKET
(Includes Case Hardened Pin)

BELOW IS A LIST OF STOCKING DISTRIBUTORS WHO SELL "BIMBA BRAND" ACTUATING CYLINDERS. SOME PROBABLY ALSO SELL OTHER BRANDS OF ACTUATING CYLINDERS PLUS SPOOL VALVES OF OTHER MANUFACTURERS.

Aberdeen Dynamics Supply Co.
Tulsa, Oklahoma 74145
918-665-0330

Adams Air & Hydraulics, Inc.
Tampa, Florida 33619
813-626-4128

Affiliated Control Eqpt. Co., Inc.
Elk Grove Village, Illinois 60007
312-640-1970

Air Component & Controls
Pennsauken, New Jersey 08109
609-665-9200

Airdraulics, Inc.
Cattanooga, Tennessee 37404
615-698-4061

Airequip-Hydraquip Corp.
Jackson, Mississippi 39209
601-969-7022

Air Equipment Company
Hialeah, Florida 33010
305-885-5371

Air Hydro Power, Inc.
Louisville, Kentucky 40218
502-451-1000

Allied-Callaway Equipment Co.
Kansas City, Missouri 64106
816-471-5505

Associate Compressor & Equip. Co.
Fresno, CA 93725
209-485-3184

Barker Air & Hydraulics
Greenville, South Carolina 29606
803-271-4910

Behco, Inc.
Ferndale, Michigan 48220
313-398-2600

Brand Hydraulics, Inc.
Omaha, Nebraska 68105
402-344-4434

Buchanan Fluid Systems
Seattle, Washington 98108
206-763-0580

Component Supply
Ontario, New York 14519
315-524-2291

Dees Hydraulics Company
Baltimore, Maryland 21221
301-574-2900

Dev-Air Corporation
Paoli, PA 19301
215-647-3677

Die-A-Matic, Inc.
York, Pennsylvania 17405
717-845-3647

Dixie Industrial Equipment Co.
Birmingham, Alabama 35211
205-780-1346

Elect Air Tool
Burbank, CA 91503
213-849-6201

Elect Air Tool
Palo Alto, CA 94306
415-494-3621

Electro Hydraulics Company
Denver, Colorado 80216
303-893-1225

Ernst Fluid Power Company
Dayton, Ohio 45414
513-890-5600

Flow Products, Inc.
Chicago, Illinois 60618
312-528-2000

Fluid Components Company
Merritt Island, Florida 32952
305-452-2358

Fluid Power South, Inc.
Chamblee, Georgia 30341
404-455-8719

Fluid Power Southwest
Richardson, Texas 75080
214-231-3456

Fluidraulics, Inc.
Cleveland, Ohio 44122
216-464-6155

Fluidraulics, Inc.
Zelienople, Pennsylvania 16063
412-776-4811

John Henry Foster Co.
St. Louis, Missouri 63132
314-427-0600

E. D. Green Corp.
Forest Park, GA 30050
404-366-5488

Murrel Haase & Co.
Memphis, Tennessee 38118
901-795-1031

Paul Hardman Company, Inc.
Mount Vernon, New York 10550
914-664-6220

Samuel Harris & Company, Inc.
Chicago, Illinois 60606
312-372-7272

Hydra Power Systems
El Paso, Texas 79901
915-593-2636

Industrial Air & Hydraulic Equip.
Detroit, Michigan 49234
313-366-8134

Industrial & Marine Equip. Co.
New Orleans, LA 70123
504-733-5030

K.E. Knotts Company
Berkeley Heights, New Jersey 07922
201-464-4800

Leinart's Inc.
Knoxville, Tennessee 37901
615-525-0363

Mid-State Machinery Co.
Decatur, Illinois 62526
217-428-4363

Mitten Hydraulics
Syracuse, N.Y. 13206
315-437-7563

Norman Equipment Company
Chicago, Illinois 60620
312-434-2300

Northern Pneumatics, Inc.
Rensselaer, New York 12144
518-286-3930

Northwest Chain Flow System
Portland, Oregon 97210
503-228-8267

Numatic Engineering
Los Angeles, CA 90039
213-666-5050

Numatic Engineering
Santa Clara, CA 95050
408-244-0115

Oyl Air Equipment Co.
Columbus, Ohio 43229
614-885-9501

Oylquip, Incorporation
Lake Charles, LA 70602
318-433-3601

Peerless Supply, Inc.
Des Moines, Iowa 50316
515-265-9905

Pneumatic & Hydraulic Co.
Baton Rouge, LA 70802
504-343-6693

Pneumatic Specialties, Inc.
Norwood, Massachusetts 02062
617-769-4266

Power Drives, Inc.
Buffalo, New York 14220
716-822-3600

Price Engineering Co. Inc.
Waukesha, Wisconsin 53186
414-784-1260

Reece Fluid Power Company
Toledo, Ohio 43623
419-473-2428

The Roden Company
Cranford, New Jersey 07016
201-276-7330

Sherwood Industries, Inc.
Cincinnati, Ohio 45244
513-231-0202

Sloan Fluid Accessories, Inc.
Nashville, Tennessee 37211
615-242-2421

Southwestern Controls
Houston, Texas 77057
713-666-2801

Sprague Air Controls, Inc.
Hingham, Mass 02043
617-337-6200

Tec-Hackett Engineering, Inc.
Fort Wayne, Indiana 46801
219-424-5504

Jack Tyler Engineering Co.
Little Rock, Arkansas 72209
501-562-2296

Virginia Hydraulics Company
Richmond, VA 23234
804-275-9222

West Virginia Fluid Power, Inc.
Huntington, West Virginia 25704
304-697-4840

The Wild Company
Denver, Colorado 80239
303-373-4840

Wisco Equipment Co., Inc.
Tempe, Arizona 85282
602-968-9063

Scott Equipment Co. Inc.
Huntersville, NC 28078
704-875-1611

John Henry Foster Company
Minneapolis, Minnesota 55406
612-721-1666

BIMBA CANADIAN DISTRIBUTORS

Cowper Company Limited
Lachine, Qeubec H8S 3A1
514-637-6746

Davis Controls Limited
Islington, Ontario M9A 4X2
416-233-3211

Davis Controls Limited
Richmond, B.C. V6V 1J3
604-278-4052

Dycon Limited
Mississauga, Ontario L4X 2E2
416-625-4350

Peerless Engineering Sales Ltd.
Burnaby, B.C. V5C 3W5
604-291-2361

Pilotair valves are manufactured by WABCO FLUID POWER DIVISION, American-Standard , 1953 Mercer Road, Lexington, Kentucky 40505 - (606)254-8031 - TWX: 510-476-8851. Their United States regional sales offices are:

Cleveland, OH 44130
216-826-0490

Union, NJ 07083
201-687-4677

Hinsdale, IL 60521
312-325-4412

Atlanta, GA 30336
404-349-3380

Houston, TX 77008
713-868-1508

Inglewood, CA 90304 (Los Angeles)
213-641-7772

By asking manufacturers or their regional sales offices you may obtain a listing of distributors who sell their brand of valves or cylinders in your area. When you find other brands of cylinders, valves and hardware please send us some information on them plus a distributor listing if possible. Adding to the manufacturer and distributor lists can make parts finding easier for everyone.

Thanks, Terry Miller

REGULATORS

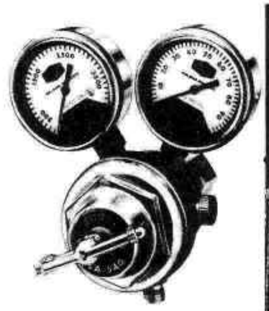
SPECIFICATIONS AND ORDERING INFORMATION

Cylinder Gas	Maximum Delivery Pressure psig	Maximum Delivery Pressure kPa	CGA Connections Inlet	CGA Connections Outlet‡	Pressure Gauges psig Inlet	Pressure Gauges psig Outlet	Model	Part No.
Inert Gases	110	759	580	B-IG	4000	200	R-1935	53L04
	500	3450		•		1000	R-1934 ✓	[✓ 53L03]

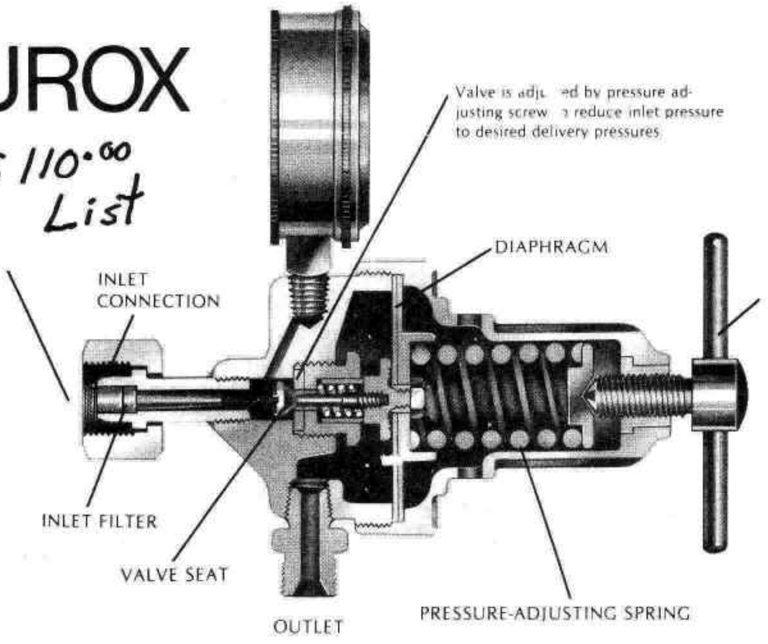
General-duty regulators are economically priced, yet ruggedly built for years of accurate trouble-free performance with minimum maintenance.

UNION CARBIDE **PUROX**

$ 110.00
List



SINGLE-STAGE



Valve is adjusted by pressure adjusting screw to reduce inlet pressure to desired delivery pressures.

CROSS-SECTION OF A TYPICAL SINGLE-STAGE REGULATOR

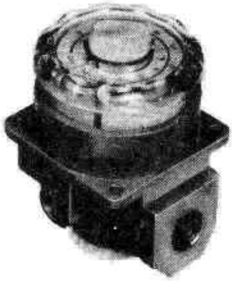
BOSTON FLUID POWER

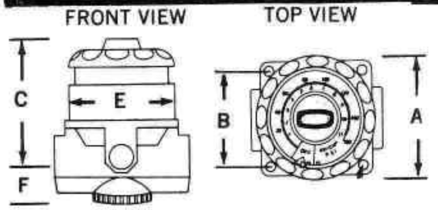
AIR PRESSURE CONTROLLERS

These Boston Gear pressure controllers are designed for use where excessive pressure drop would be encountered with conventional regulators and where a low silhouette is desirable. This unit can be easily panel mounted. Full pressure range can be selected in less than 360° of knob rotation. Quick adjust feature and high exhaust capacity make it possible to use as a 3-way valve. Adjustable stop is standard for limiting minimum or maximum outlet pressure.

+Optional Tamper Resistant Kits allow presetting at both minimum and maximum outlet pressure settings.

BOSTON GEAR

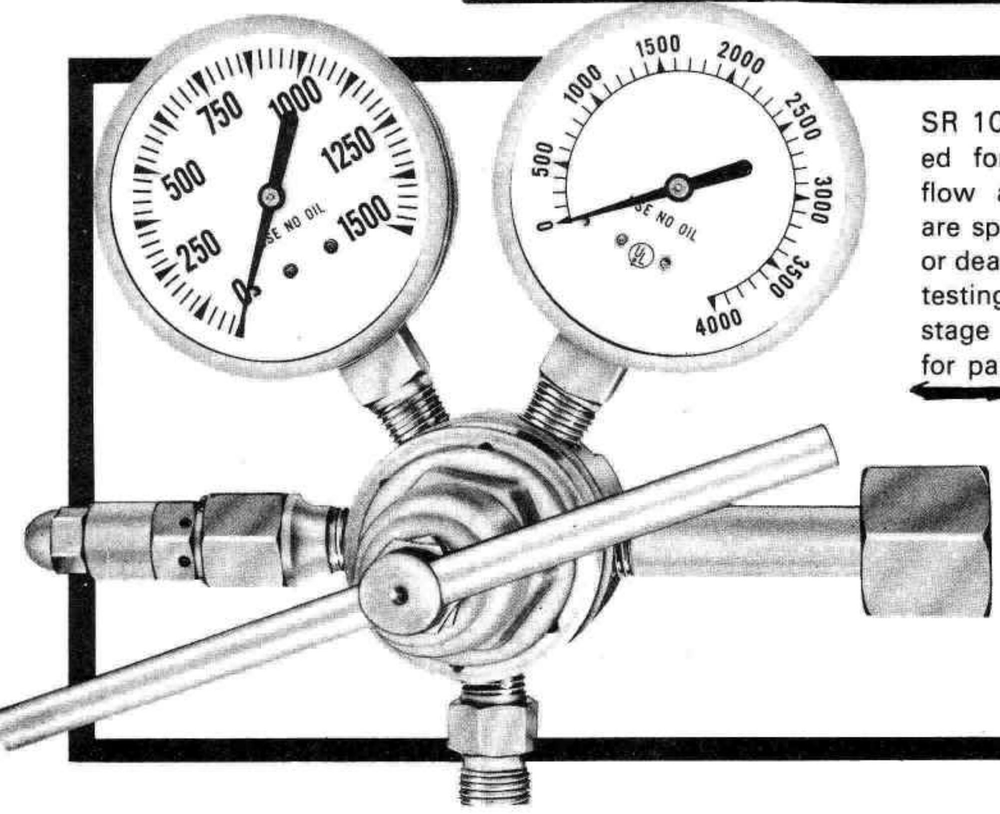




ORDER BY CATALOG NUMBER

Pipe Size (NPT)	Catalog Number	Item Code
1/4	E42620	70394
3/8	E42630	70396
1/2	E42640	70397

VICTOR



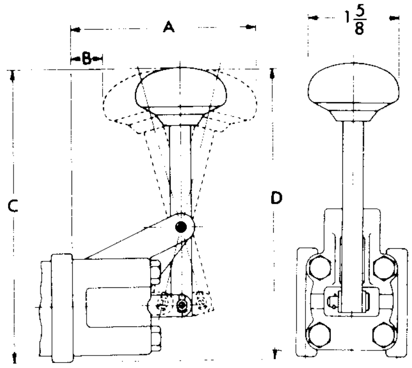
SR 10 Series Regulators are designed for accurate high pressure/low flow applications. These regulators are specially suited for use on closed or dead end systems such as pressure testing vessels for leakage. Single-stage construction. May be ordered for panel mounting.

Dimensions:
2"W x 4⅞"H
Weight:
2 lbs. 7 oz.

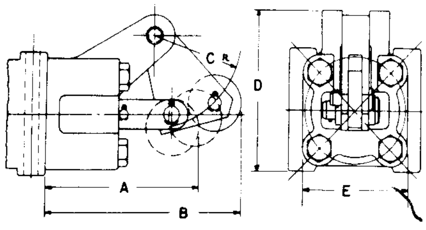
GAS SERVICE	SELECT MODEL NUMBER
Oxygen	SR 10
Air Inert Gas ✓	[✓ SR 11]
Methane Hydrogen	SR 12
CO_2	SR 13
N_2O	SR 13

FM APPROVED

SPOOL VALVE OPERATORS



LEVER OPERATOR



CAM OPERATOR

ALINABAL Sales Offices:

Division of MPB Corporation

EAST — MPB Corporation, 28 Woodmont Road, Milford, CT 06460, Tel: 203-877-3208, TWX: 710-462-1178.

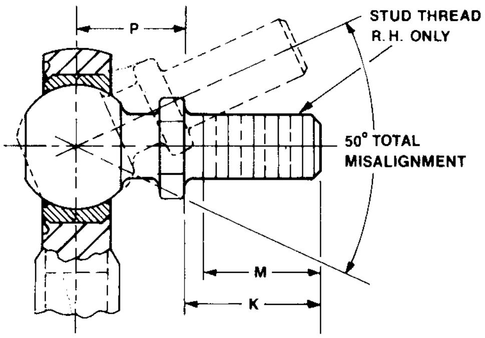
CENTRAL — MPB Corporation, 2775 W. Algonquin Road, Rolling Meadows, IL 60008, Tel: 312-259-7800, TWX: 910-687-3374.

WEST — MPB Corporation, 1101 Flower Street, Glendale, CA 91201, Tel: 213-245-6413, TWX: 910-497-2083.

CANADA —

RHP CANADA LTD., Head Office, 5385 Pare St., Montreal, Quebec H4P1P9, Tel: 514-342-1490, TWX: 610-421-4469.

Shank Thread Class UNF-2	Angle of mis-alignment ● Degrees	Static load rating (lbs.) Male	Static load rating (lbs.) Female	STUDS: DIMENSIONS IN INCHES + K − .010	+ P − .030	M (ref)	Stud Thread Class UNF-2A	Studded Static Load Rating (lbs.)
10-32	34	895	1755	.500	.516	7/16	10-32	250
1/4-28	34	1650	2600	.562	.485	1/2	1/4-28	550
5/16-24	28	2600	3500	.687	.547	19/32	5/16-24	850
3/8-24	30	3950	3950	.906	.662	13/16	3/8-24	1200
7/16-20	32	4800	4800	1.125	.843	1	7/16-20	1600
1/2-20	32	5500	5500	1.125	.875	1	1/2-20	2000
5/8-18	30	7000	7000	1.500	1.000	1-3/8	5/8-18	2400
3/4-16	25	8000	8000	1.812	1.188	1-5/8	3/4-16	3400



Studs — Alinabal precision mounted steel studs are available in standard or special designs to facilitate assembly in right angle connections and contribute to smooth operation and high performance.

To specify studs, add S before size number. Example: VMS-3-G.

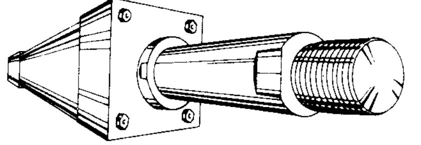
There are other brands of ball-joints. They can be obtained with threads to match rod end of actuating cylinders

BOSTON FLUID POWER PRODUCTS

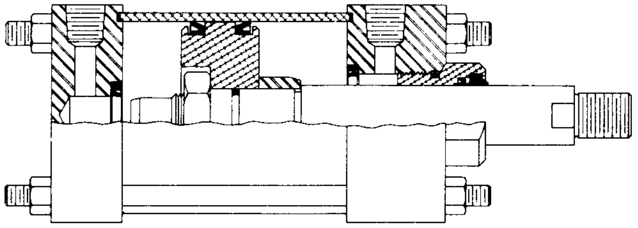
NFPA CYLINDERS - MEDIUM DUTY

250 PSIG AIR
500 PSI OIL (NON-SHOCK)
1½-6″ BORES

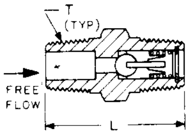
BIMBA®



This double acting cylinder series is designed to meet industry's requirements for a reliable and economical unit tailored to fit the low to medium pneumatic pressure range as well as to satisfy applications in low pressure hydraulic systems.

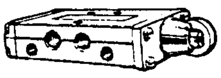


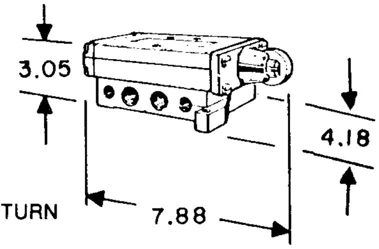
CHECK VALVE



SIZE NPT
1/4
3/8
1/2
3/4

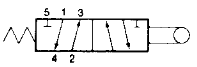
2-POSITION, 5-PORT - SUBBASE,
SIDE PORT - NONDETENT





CAM DIRECT - SPRING RETURN

PORT SIZE	CATALOG NUMBER	ITEM CODE
1/4	E72DA00-PS1-PR0	71909
3/8	E72EA00-PS1-PR0	71926



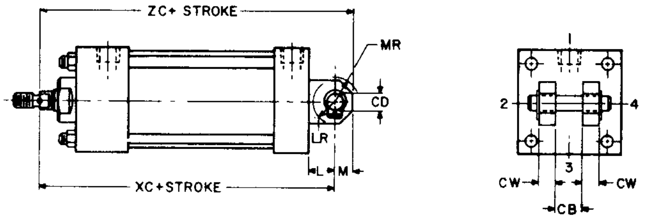
BOSTON FLUID POWER PRODUCTS

NFPA CYLINDERS MEDIUM DUTY

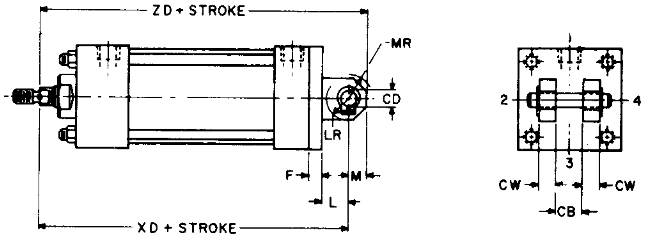
BE10 "REBEL"

250 PSIG AIR
500 PSI OIL (NON-SHOCK)

CAP FIXED CLEVIS MOUNTING - NFPA MP1



CAP DETACHABLE CLEVIS MOUNTING -NFPA MP2



BORE	ROD	CB	CD	CW	F	L	LR	M	MR	XC	ZC	XD	ZD
1 1/2	5/8"	3/4	1/2	1/2	3/8	3/4	5/8	1/2	19/32	5 3/8	5 7/8	5 3/4	6 1/4
	1	3/4	1/2	1/2	3/8	3/4	5/8	1/2	19/32	5 3/4	6 1/4	6 1/8	6 5/8
2	5/8	3/4	1/2	1/2	3/8	3/4	5/8	1/2	19/32	5 3/8	5 7/8	5 3/4	6 1/4
	1	3/4	1/2	1/2	3/8	3/4	5/8	1/2	19/32	5 3/4	6 1/4	6 1/8	6 5/8
2 1/2	5/8	3/4	1/2	1/2	3/8	3/4	5/8	1/2	19/32	5 1/2	6	5 7/8	6 3/8
	1	3/4	1/2	1/2	3/8	3/4	5/8	1/2	19/32	5 7/8	6 3/8	6 1/4	6 3/4
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	1 3/8	1 1/4	3/4	5/8	5/8	1 1/4	1	3/4	7/8	7 1/8	7 7/8	7 3/4	8 1/2
4	1	1 1/4	3/4	5/8	5/8	1 1/4	1	3/4	7/8	6 7/8	7 5/8	7 1/2	8 1/4
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5	1	1 1/4	3/4	5/8	5/8	1 1/4	1	3/4	7/8	7 1/8	7 7/8	7 3/4	8 1/2
	1 3/8	1 1/4	3/4	5/8	5/8	1 1/4	1	3/4	7/8	7 1/2	8 1/8	8	8 3/4
6	1 3/8	1 1/2	1	3/4	3/4	1 1/2	1 1/4	1	1 7/32	8 1/8	9 1/8	8 7/8	9 7/8
	1 3/4	1 1/2	1	3/4	3/4	1 1/2	1 1/4	1	1 7/32	8 3/8	9 3/8	9 1/8	10 1/8

Browning

Spur Gears

547

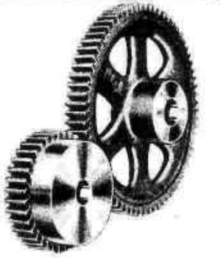
6 Pitch **1½" Face** **14½° Pressure Angle**

Stock Steel Finished Bore Spur Gears

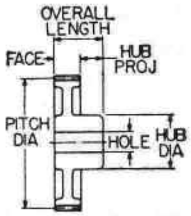
NSS618	3.000	3.33	18
NSS620	3.333	3.66	20
NSS621	3.500	3.83	21
NSS624 ←	4.000	4.33	24 ✓
NSS627	4.500	4.83	27

BOSTON SPUR GEARS

14½° PRESSURE ANGLE
(Will not operate with 20° spurs)
6 DIAMETRAL PITCH
1-1/2" FACE
STEEL & IRON MATERIAL



BOSTON SPUR GEARS



PRESSURE ANGLE 14½°
(Will not operate with 20° spurs)
DIAMETRAL PITCH 6
FACE 1-1/2"
MATERIAL STEEL & IRON

MANUFACTURED BY

F. C. Kingston Company

ESTABLISHED 1908
1007 NORTH MAIN STREET • TELEPHONE (AREA CODE 213) 221-2106
LOS ANGELES, CALIFORNIA 90012

Minimum billing $15.00

$9.00 List

POP SAFETY VALVE – ✓

Fig. 115 A.S.M.E. Standard, N.B. Certified. Same construction as Figure 114, except they are equipped with manual lift ring or toggle lift device. Available in ¼", ✓ ⅜" and ½" N.P.T. sizes. Pressure settings from 10 P.S.I. to 300 P.S.I. in ¼" N.P.T size and 10 PSI to 275 P.S.I. in ⅜" & ½" N.P.T. sizes. Maximum temperature 250°F (121°C)

115

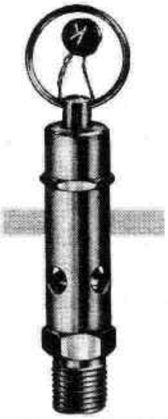
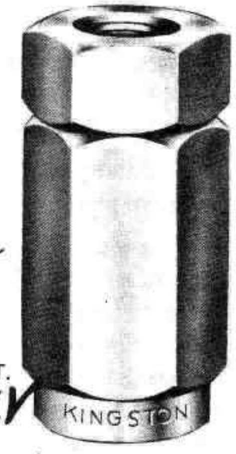


Fig. 226 — Inline check valves are the same configuration as Fig. 226A, except without the unloader port. Standard seat disc is of bonded Buna-N material, Rulon is available on request. These valves operate equally well in vertical or horizontal position.

$9.00 List ✓



"KINGSTON"

Fig. 226
F.P.T. F.P.T.
← ¼" x ¼" ✓
⅜" x ⅜"

Fig. 226

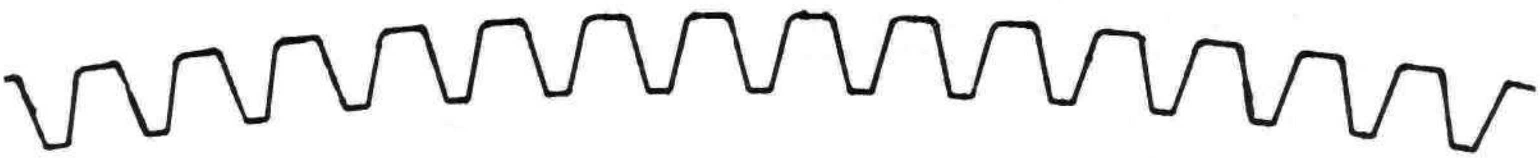
VERTICAL CHECK VALVES

See your area bearing supply or industrial supply for gears and bearings.

A local manufacturer is cutting the 270 tooth gear (1) in Missouri for those that want one. It's kinda funny in a way. You see, I cut my first gear out of plate steel with an electric Black and Decker jig saw. It took three weeks, 90 saw blades and two saws. This gear made the hard way is not perfect but it works. Gear (1) machined and now available is not perfect but almost perfect. Should anyone wish to cut such a gear with a 1½" dia. hole in the center with a jig saw as I did, that's great! Bring this gear (1) to me and if it is close to as good as the one I cut for air car 1, I will give you $300.00 for it and not bat an eyelash.

The point I wish to make is this; Please check with gear manufacturers as to what it would cost you to buy such a gear before asking me what I have to get for such a gear.

To study gears pick up a Browning and a Boston gear catalogue from a bearing supply firm. In addition to gear sizes a lot of extra information is in these catalogues including bearings.



Above is an outline of the 6 pitch, rack gear tooth configuration of number (1) drive gear.

DESIGN OR HOW CAN ONE SEE THE END RESULT BEFORE STARTING TO BUILD AN AIR POWERED CAR

You start with the gear ratio of 270 teeth to 24 teeth to 24" diameter tires. Remember that if tires are not 24" diameter you will have to add to or subtract from the number of teeth on the small gear to get the same distance down the road. You start with a 2½" bore actuating cylinder which is first to use air in the pneumatic system. You use a 4" crank throw and stroke of 8" for the cylinder. You could use other gear ratios even other bore cylinders and stroke lengths, but remember this can change results. Next you add cylinder number two which is larger in diameter 4" but also having an 8" stroke. This cylinder uses the exhaust air from number 1 cylinder. Air pressures at maximum with a number one cylinder rated pressure of 250 P.S.I. could be 250 P.S.I. to number 1 cylinder, a tank (19) pressure of 85 P.S.I. giving number 2 cylinder an operating pressure of about 80 P.S.I. due to pressure drop. The larger bore of cylinder 2 at 4" diameter enables it to deliver a force at the crank nearly equal to number 1 cylinder. So you see that the second actuating cylinder doubles the power of the pneumatic engine but without using any more air to do this. The amount of air which can be used is controlled by cylinder number 1. A two cylinder car can be expected to obtain a little more than twice the speed obtained on one cylinder. A three cylinder car can be expected to obtain three times the speed of a single cylinder car. A four cylinder car can be expected to obtain about 9 M.P.H. less than four times the speed of a single cylinder car. On the above figures for a two, three or four cylinder car it should be noted that a number one cylinder pressure of 250 P.S.I. and all other factors such as gear ratio and tire diameter are the same. On the above figures for a two, three or four cylinder car, a car weight increase of 50 pounds for each cylinder is allowed for. As an example a four cylinder car would weigh approximately 150 pounds more than a single cylinder car due to the weight of the actuating cylinders, tanks (19) and their related hoses and valves. You can see the power increase verses the weight increase is well worth it, considering the fact that this power and speed increase is easily obtained without using any more air per mile down the road.

While a five or six cylinder engine can easily be built I do not have enough actual experience to quote any speed or power figures at this time. I do not see any need for a five or six cylinder engine in order to design a production car. A six could be a radial engine with one timing cam and one pig valve cam. The first cylinder should be 2" bore rated at 500 P.S.I. with 450 P.S.I. used for a maximum pressure. Cylinder six could be 6" bore with other cylinder sizes used between one and six. I do see a need for a three cylinder car and the fact that a four cylinder car will be manufactured eventually. A three or four cylinder engine is easy to build. A radial engine with all cylinder rod ends connected to one common crank pin with a 4 inch crank throw. Only one timing cam is needed and only one pig valve cam.

On a three cylinder engine number one cylinder pig valve could port air during midstroke to the tank (19) that supplies air to number three cylinder instead of venting this air to the atmosphere. Number two cylinder pig valve would vent to the atmosphere.

On a four cylinder engine number one cylinder pig valve ports to number 3 cylinder pressure tank (19). Number 2 cylinder pig valve ports to number four cylinder pressure tank (19). Number 3 cylinder pig valve would vent to the atmosphere. Because, of increased power of three and four cylinder cars gear ratio changes to effect even better air mileage could be made as follows. 21 tooth gear on a three cylinder car. 19 tooth gear on a four cylinder car. On gear ratio design a few things need mentioning. The experts tell me that 18 teeth is the lowest number of teeth that can be used without undercutting of the tooth surface. Also, they say less teeth would be inefficient in the transmission of power. I read in an engineering text published in 1932 that a spur gear with anything less than 21 teeth is useless in the transmission of power, whereas a leading gear manufacturer today says 18 is the minimum number with undercutting as the main cause for power loss. Questions arise as to where the break or loss in power transmission occurs in regards to teeth numbers in a spur gear. I would like to hear from others who may have information on this teeth number question. The larger drive gear with 270 teeth was not a regular manufactured gear in May 1979, and had to be cut out by hand. It is now available being punched out one tooth at a time on a punch press utilizing an indexing head to locate each tooth. One question often asked is; "Can the gear be made smaller?" Perhaps the gear could be made smaller or maybe two gears could be used instead of one. This two gear setup would give more tooth friction also more bearing friction, but, it is probably workable. One thing you cannot get away from, however, is the gear ratio including tire diameter, which determines air mileage and the ability of pressure equalization transfer to work effeciently. Tooth pitch could be changed from a 6 pitch to the smaller 8 pitch which could give you a smaller 30" diameter main drive gear. I chose 6 pitch because 8 pitch did not seem strong enough as I want eventually to put a disc type brake on the drive gear for a vehical brake. I didn't think an 8 pitch was strong enough. If you cut teeth number below 270 you would have to cut the small spur gear teeth number, or increase tire diameter. A main drive gear (1) with an 8 pitch tooth configuration with 270 teeth would be 30" diameter, then look at a 24 tooth 8 pitch spur gear. It is a pretty small gear in diameter and shaft size. Reporters often call the drive gear a large flywheel but it is not a flywheel, because, it does not turn fast enough to give usefull flywheel action.

The specifications for a production car suited for town driving has to include several things; Enough air storage capacity 1,500 cu.ft. to attain a respectable distance per airup. A total car weight light enough to attain in town driving speeds. A pneumatic engine with enough power to do the job, with the first actuating cylinder controlling air use per mile and the other cylinders adding more power at no cost in air mileage.

As a review of required specs. fifteen hundred cubic feet of air could be four "T" size cylinders plus a scuba tank. Cylinders can be had in any practical length. Two ten ft. tanks 9 5/8" diameter would do the job and they can be had in steel construction. Aluminum cylinders weigh about 30 to 40 percent less. Some aluminum tanks are available now with diameters of 8½" rated 2,250 P.S.I. and more. One firm in California specilizes in wrapping aluminum cylinders with glass fiber to hold higher pressures. While aluminum cylinders are not needed for a production car I trust someone with enough capital and foresight will see a need and get with the job of producing special aluminum cylinders for air cars. Aluminum cylinders of the right length and diameter could save about two hundred pounds car weight.

Car frame weight can be kept light enough without using aluminum, but, we are bound to see some aluminum used where possible. Tubular frames look good.

AIR CAR MAINTENANCE

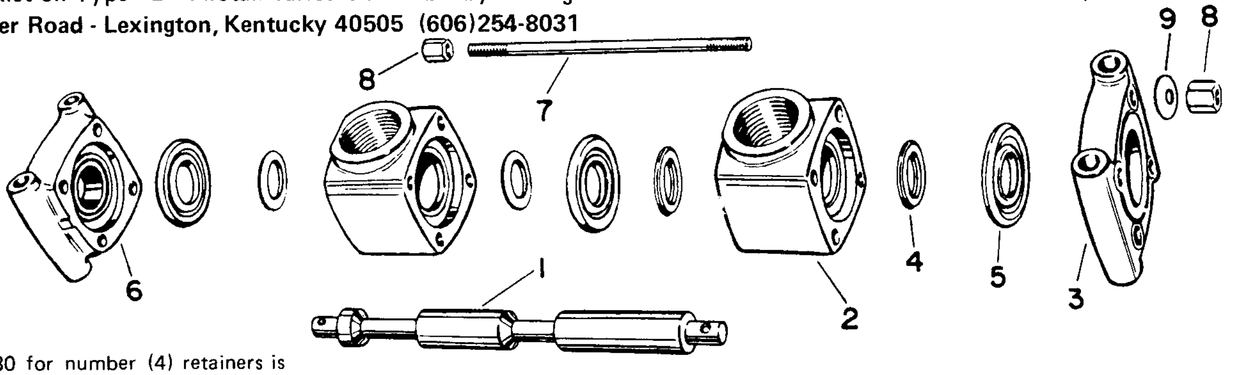
The gear ratio of Air Car 1 is 270 teeth to 24 teeth and is the ratio I recommend for your first car. This ratio would be 11¼ to 1. We have used an axle gear with 21, 24, and 40 teeth at different times to determine the maximum engine r.p.m. at which my manifold (16) will function without losing it's effeciency. A 24 tooth axle gear coupled with the outside tire diameter of 24" and your car would travel 70.65 feet per engine r.p.m. A total of 75 engine revolutions would get you one mile down the road. Fifty revolutions per minute is 40 m.p.h. One might think an axle gear with 40 teeth would make the car faster because of the increased power to the axle. This is not so, because the manifold (16) requires a lower crank shaft r.p.m. to function effeciently. This works out just fine when you consider the need for good air mileage and minimum wear on the total engine obtained with such low r.p.m.

Wear between number (1) and number (2) gears is very slight. I don't know how long they might last. I cut number (1) gear teeth with a jig saw. They are not perfect at all yet they wear o.k. so far. The crank shaft bearings are rated for continous duty at much much higher R.P.M. than 60 R.P.M. Same with the axle bearings and the load rating of these bearings far exceeds any load experienced in driving. I'm no bearing expert but, I can't see them wearing out any time soon. The pillow block bearings used for the valve timing mechanism should last for years in this application, if oiled regularly. The students from Buffalo, Oklahoma used wood blocks for bearings and they worked just fine. Valve timing bearings for a production car will be much more refined and cheap to maintain if ever necessary.

The ball joints (7), I don't know much about. They are a bronze bearing and I oil them with 20W non-detergent oil if they look dry. A ½20 thread ball throttle joint can be purchased from an auto parts store for less than four dollars. The more expensive alignaball brand would cost at least seventeen dollars retail from a bearing supply store. The actuating cylinders manufactured today are really honed to precision. Double wall actuating cylinders can be disassembled easily for seal replacement. Other actuating cylinders with tie-rods on the outside can also be overhauled by replacing seals. The number (1) actuating cylinder shown in the pictures of air car 1 is a disposable type which cannot be overhauled. Number (2) actuating cylinder is a double wall cylinder of which the seals can be easily replaced. Prices for replacement seal kits are listed somewhere on this sheet. Spool type timing valves may or may not be of a type you can replace seals. Seals can be replaced on the spool type valves shown in pictures of air car 1. Production cars will have actuating cylinders and timing valves that are condusive to easy seal replacement. Seal replacement should be a consideration when buying valves and cylinders.

Old air car patents back to 1894 show pneumatic cylinders tied direct to the axle like a childrens pedal car. Actuating cylinders were to be packed at the rod end with cotton soaked in oil. A far cry from the stainless steel available today in actuating cylinders. Often two actuating cylinders are shown to give a smoother ride. But, just think of how fast and how many times these cylinders would have to actuate to get a mile down the road. Some old drawings show in addition to the actuating cylinders, two more pistons on the front end driven by the axle to pump up air to use for motive power. Back then you drew up a machine. If it had not been thought up before you got a patent. The point I wish to make is this; Air car 1 is not a machine to replinish it's air supply, but, rather a machine to get as far down the road as possible with the least amount of air, while at the same time using the air several times, getting as much power as possible, while at the same time not running at a speed which would cause rapid wear on actuating cylinders. One other point is that this specific gear ratio including tire diameter, is the ratio that gives the desired actuating cylinder speed to allow for the saving and re-use of air in the next and larger cylinder. Pressure equalization transfer requires this lower crank shaft R.P.M. for it's most effecient functioning. I'll admit that it is kinda flukey that this would all fall into place for me of all people. The right gear ratio which if it had not been real close would have kept me from learning about air saving and re-use. It's scarey sometimes but, it works. You go with what works. I think the economy of air car maintenance is evident.

Overhaul parts for actuating cylinders and spool valves are available through distributors. In checking I have found most manufacturers to be reluctant to quote precise overhaul parts kit prices, referring you to your local distributor instead. Perhaps, it is because of differences in freight and the desire of distributors to be able to determine their own prices for parts they sell. Most distributors are not accustomed to selling valves and actuating cylinders for air powered cars. Generally from several price checks, I have found that overhaul kits can be purchased for less than one fourth the selling price of the valve or cylinder. Most manufacturers will supply detailed service literature on request by mail. You can learn much, much more from the service literature than from the sales catalogs. As an example; a 20 page service information booklet on Type "D" Pilotair valves is available by writing to: **WABCO FLUID POWER DIVISION, AMERICAN-STANDARD 1953 Mercer Road - Lexington, Kentucky 40505 (606)254-8031**



The retail price May 1980 for number (4) retainers is $1.57 each the packing ring (seal) number (5) priced at $2.49 each. The valve shown with two body segments can be used for valve (15) (pig valve).

Part number (5) provides a seal between body segments and acts like an o-ring seal in relation to the stem (spool). Retail cost of three replacement retainers and three packing rings is $12.18. List price for this two way valve is $57.45. Discounts of 15% off list price is about average when you buy a few items at one time.

REPAIR PARTS LIST

			✓	✓				
1 Stem	2 Body Segment	3 Cover (B End)	4 Retainer	5 Packing Ring	6 Cover (A End)	7 Tie Rod	8 Nut	9 Washer

"D" PILOTAIR Valves are spool type directional valves with two-way, three-way or four-way operation. They are built with open exhaust ports and with tapped exhaust ports. With different valve stems the three-way and four-way valves may have a mid-position where all ports are lapped, supply is connected to delivery or delivery is connected to exhaust.

The "D" PILOTAIR Valve is operated by lever, button, pedal, treadle, cam, pilot cylinder or solenoid. These operators may be put on either end or both (see OPERATION). The operator may have springs to return the valve stem to its normal position when the operating force is removed.

OPERATION

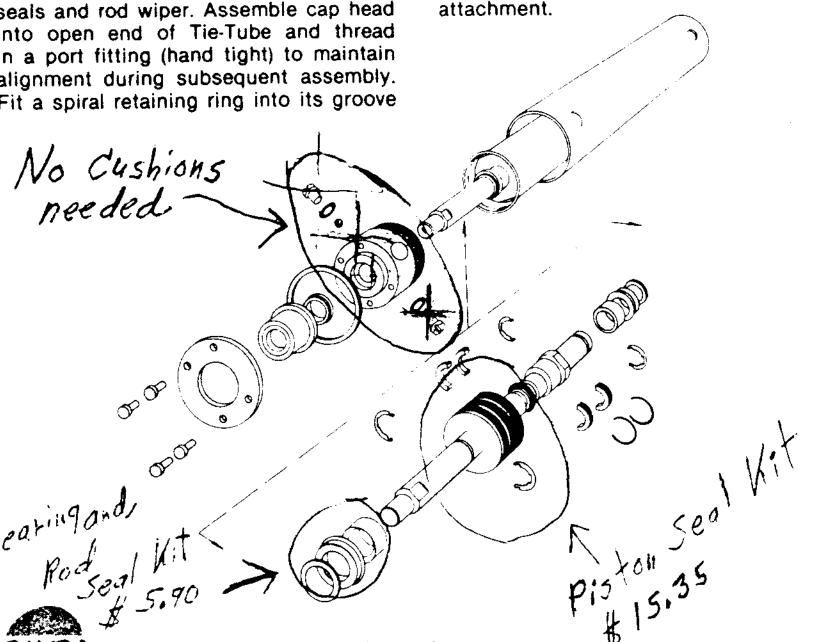
To operate a "D" PILOTAIR Valve a manual, mechanical, pneumatic, hydraulic, or electrical force is applied to its operator. This force moves the valve's stem which, in moving to another position, opens and/or closes internal passages in the valve. The accompanying diagrams illustrate how the valve's stem opens and closes its passages.

Some stems have two positions - one at each end of its travel. Some stems have three positions - the third being midway between the end positions. In their end positions, three and four-way valves have one or more passages open. Moving the stem to its other end position closes the passages that were open and then opens the passages that were closed. The mid-position results in one of three conditions - al' ports lapped, supply connected to delivery or delivery connected to exhaust.

DOUBLE-WALL™ AIR-CYLINDER GENERAL REPAIR INSTRUCTIONS

DISASSEMBLY -
Remove 4 cap screws, bearing retainer plate, rod bearing and rod seal. Using a screw driver, remove spiral retaining ring. Withdraw Piston rod assembly which will also remove rod end head. Remove spiral retaining ring from cap end of cylinder and remove cap end head. Stainless steel inner tubing will usually withdraw with the cap end head.

REPAIR AND REASSEMBLY -
The piston and rod can be disassembled if desired, however, it is not necessary for normal repair. These parts are secured with a chemical thread lock, which must be cleaned from all parts, and reassembly must be with a similar suitable locking agent. If the piston or rod is to be replaced it is recommended a new, preassembled, piston and rod kit be ordered. Cushion retaining split rings are removed with a screw driver and replaced by squeezing with a pair of pliers. Clean all parts and replace all static seals, piston and rod seals and rod wiper. Assemble cap head into open end of Tie-Tube and thread in a port fitting (hand tight) to maintain alignment during subsequent assembly. Fit a spiral retaining ring into its groove in the Tie-Tube. Insert the piston and rod assembly, complete with all seals and piston bearing strip, approximately midway into the inner stainless tubing. This assembled unit may then be fitted into the Tie-Tube/Cap head assembly. Slip the rod end head over the piston rod, locating in place in the open end of the Tie-Tube, and thread in a port fitting (hand tight) to maintain alignment. Fit the spiral retaining ring into the Tie-Tube groove. *Caution:* The internal wave spring must be compressed to allow the spiral retaining ring to snap completely into its groove. In the event it is not properly home, the bearing retaining plate/spacer and cap screws will not fit up and seat completely. Tapping may be necessary to compress the wave spring, use a dift pin aligned parallel to the piston rod and tap lightly with a hammer. Replacement of the rod seal, bearing and wiper unit, retaining plate and associated cap screws completes the assembly of the basic cylinder. See instructions packed with the various mounting kits for their attachment.

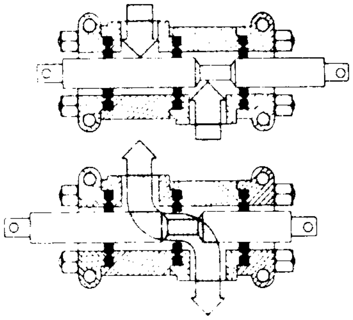


No cushions needed

bearing and Rod Seal Kit $5.90

Piston Seal Kit $15.35

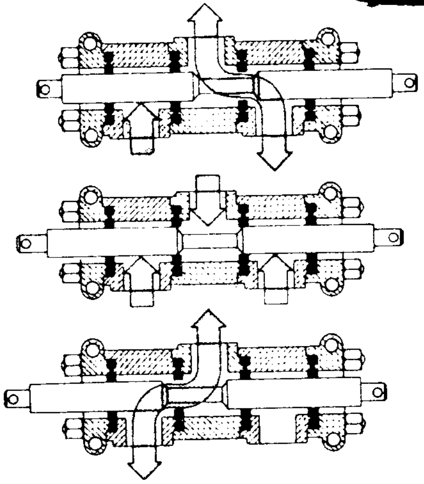
BIMBA MFG. CO., Monee, IL 60449



Valve (15)

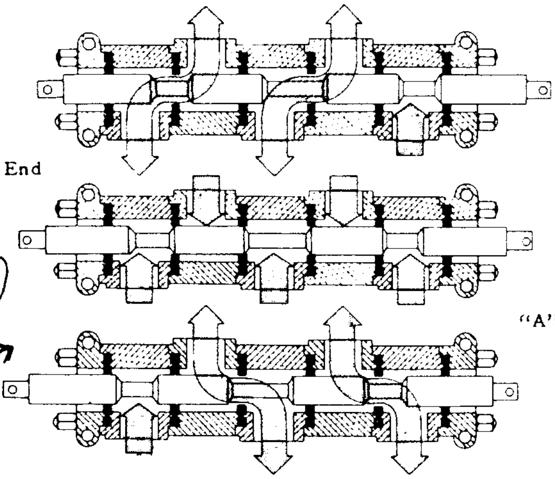
a substitute for pig drinking valve

2-WAY VALVE



Valve (11)

3-WAY VALVE, TAPPED EXHAUST
CLOSED CENTER POSITION



Valves (12) & (24) Timing Valves

4-WAY VALVE, TAPPED EXHAUST
CLOSED CENTER POSITION

AIR - STATIONS

Air to fill air car tanks cannot be had at regular gas stations as their compressors seldom pump to over 180 pounds. The total concept regarding use of air powered cars for town transportation necessitates having one or more Air Stations in each town or city. Each air station consists of storage tanks, one or more four stage air compressors plus the necessary filters, regulators, plumbing and hose for filling the air car's tanks. An "airup" can be completed in minutes from the reserves of compressed air contained in pressure tanks at the air station site. Storage tanks can be above or below ground. Below ground storage tanks can be much larger than above ground tanks. Below ground storage tanks shaped like butane or other liquid gas tanks can hold more volume of air at less cost per tank. Below ground tanks have to be set in reinforced concrete. While above ground tanks are limited to the smaller diameters, the length of such tanks can be up to 40 ft. or more. Well caseing pipe with threaded bull plugs can be used for storage tanks. Also, compressed air cylinders can be purchased in 40 ft. lengths. Standard compressed air cylinders can be manifolded together to provide air storage. In a community owned air station air is sold to car owners for a rate per mile according to the range of a particular air car. In a non-profit corporation type air station air can be sold to stockholders and charged against the odometer reading of the stockholder's car. An air station for use by stockholders can be enclosed by fence or building with keys to the entire station available to stockholders who are in charge of overseeing the compressor maintenance. Stockholder family members and others driving air cars of stockholders would only need to carry keys to gain them access to the airup hose. Compressors of 20 h.p. and above have hour meters which record compressor or time. Hour meter readings plus electrical use readings when compaired to air sold to stockholders provide a clear picture of air station profitability as far as paying it's own way. The stockholder who acts as maintenance officer need not be paid in cash, but, rather with a certain amount of air per month. Cost of air per mile charged to stockholders could be as little as two cents. A rate of electrical cost times two is believed enough to maintain an air compressor including overhaul or valve jobs. It is of note that a compressor does not wear if it is not run and income for maintenance is in proportion to it's use in an air station application. I have documented the electrical consumption of two air compressors. This was done by actually seeing and recording electric meter readings during the filling of "T" size compressed gas cylinders. The information is as follows; The electrical requirements listed in my original invention disclosure about a 20 h.p. compressor were obtained with the help of the Joplin Gas Company, Joplin, MO. They have a 20 h.p. 4 stage air compressor used to fill "T" size cylinders with natural gas. They run several of their service trucks on natural gas. The fact that this compressor has it's own separate electric meter allowed me to obtain very accurate energy consumption readings.

Another compressor checked for electrical consumption was a smaller unit owned by the Webb City Fire Dept., 35-37 Main street, Webb City, MO 64870. It is used to fill "T" size cylinders with compressed air. This fire dept. uses several "T" size cylinders manifolded together for air storage. Firemen use these tanks as an air station to fill personal breathing tanks used for life support and rescue operations. Such a fill system utilizing several storage tanks is called a cascade system. You can probably see this type system at your fire station or a scuba diver speciality store that fills scuba tanks. This compressor is small but productive for the size. The manufacturer of the Webb City compressor is; American Bristol 1600 W. 240th St., Harbor City, California 90710 (213)543-5981, model 4E1, List price $2,365.00. This compressor is 2 h.p. It required 2.6 hr. and 4 killowatts of electricity to fill a "T" size cylinder. Cubic feet per min. air delivery for compressors can vary some due to altitude and plumbing for intake and outlet air. Air compressors are more energy efficient as horse power is increased. A 50 h.p. compressor is generally more energy efficient than a 20 h.p. unit. Compressors are available with 100 h.p. ratings and above. A 15 h.p. or 20 h.p. compressor is large enought to set up an air station. A larger 50 h.p. or 100 h.p. compressor could be added later with the 20 h.p. compressor used for back-up. A central compressor pump station is practical economically. Storage tanks at various locations within a city can provide air stations in various locations within a city.

Impact Extrusion • Luxfer's cold impact extrusion press, one of the largest in the world, exerts up to seven million pounds of pressure on the aluminum slug, forging the metal into a seamless cylinder.

Luxfer responded to the challenge by developing a new concept that combined the space age technology of glass reinforced composites with an aluminum cylinder.

Today Luxfer has adopted this new design for commercial applications and is now manufacturing large quantities of similar cylinders.

Long tanks up to 40 feet in length suitable for Air Station air storage are manufactured by; Western Sales and Testing - 114 East 46th, Amarillo, Texas 79101 - 806-373-6811. Oil well pipe 9 5/8 O.D. with a wall thickness of .352 is available in 40 ft. lengths. A round end cap called a (bull plug) screws into the ends to form a tank. I understand this is steel manufactured in Japan and is used by one or more cylinder manufacturers to make compressed gas cylinders. Check yellow pages for listings like; Oil Well Sales, Pipe and Supply, Oil Field Supplies or Pipe and Steel. Some major manufacturers of steel compressed gas cylinders are listed below. Write for a catalog.

Chesterfield Cylinder Co. - U.S. 64 & Raleigh St., Enid, OK 73701 - 405-233-6300
The Marison Company - 50 North River St., South Elgin, Illinois 60177 - 312-742-2500
Taylor-Wharton - P.O. Box 1742, 2900 William Penn Ave., Easton, Penn. 18042 - 215-258-7271
Industrial Cylinder Co., 4601 West Lincoln Ave., West Milwaukee, Wisconsin 53219, 414-647-8222

ALUMINUM COMPRESSED GAS CYLINDER MANUFACTURERS

Two major manufacturers of aluminum compressed gas cylinders suitalbe for air powered cars are listed below. Two thousand cubic feet of compressed air can be carried in wrapped aluminum cylinders at a total cylinder weight of only 550 pounds. ALUMINUM CYLINDERS - Luxfer USA Limited, 1995 3rd St. Riverside, CA 92507 - 714-684-5110 - Contact Don W. Clervi. Commonwealth Industrial Gases, 19-21 Bowmans Rd, Maralong Road, 2148 New South Wales, Australia - 621-5666. Contact John Gwynne.

FINANCING AN AIR STATION

The first air stations could come into being by civic participation toward funding. The selling of air coupons worth 500 miles of air for $10.00 per coupon. A rate of 2 cents per mile.

Large purchases up to $1000.00 could be solicited from civic minded people with a guarantee that even though they may not own an air car in the future their coupons would be sold first when desired to people needing air. A local bank account could handle the funds thus raised with deposit receipts being issued for all money deposited into the air station account. Upon completion of the air station ready for quick-fill of air car's tanks, depositors could exchange their deposit receipts for air coupons, as needed. Air car owners could purchase air coupons only from the air station bank account until all civic loans (loans made to set up the station) are paid.

Persons making a purchase of air coupons to finance the original air station should also receive interest on their money in the form of additional coupons at a standard bank rate for loans say 12%. A rate of 12% paid to civic minded investors in the form of air coupons redeemable in cash as air car owners purchased air would be an encouragement to withdraw some money paying less interest from savings to invest at a larger interest for the money, in an air station. The larger investors could form a non-profit corporation to handle management of the station accounts.

The bylaws of such a corporation should stipulate that no money may be withdrawn from the funds for profit. Also, proceeds would be re-invested in enlarging the station, as required, or held in reserve for maintenance.

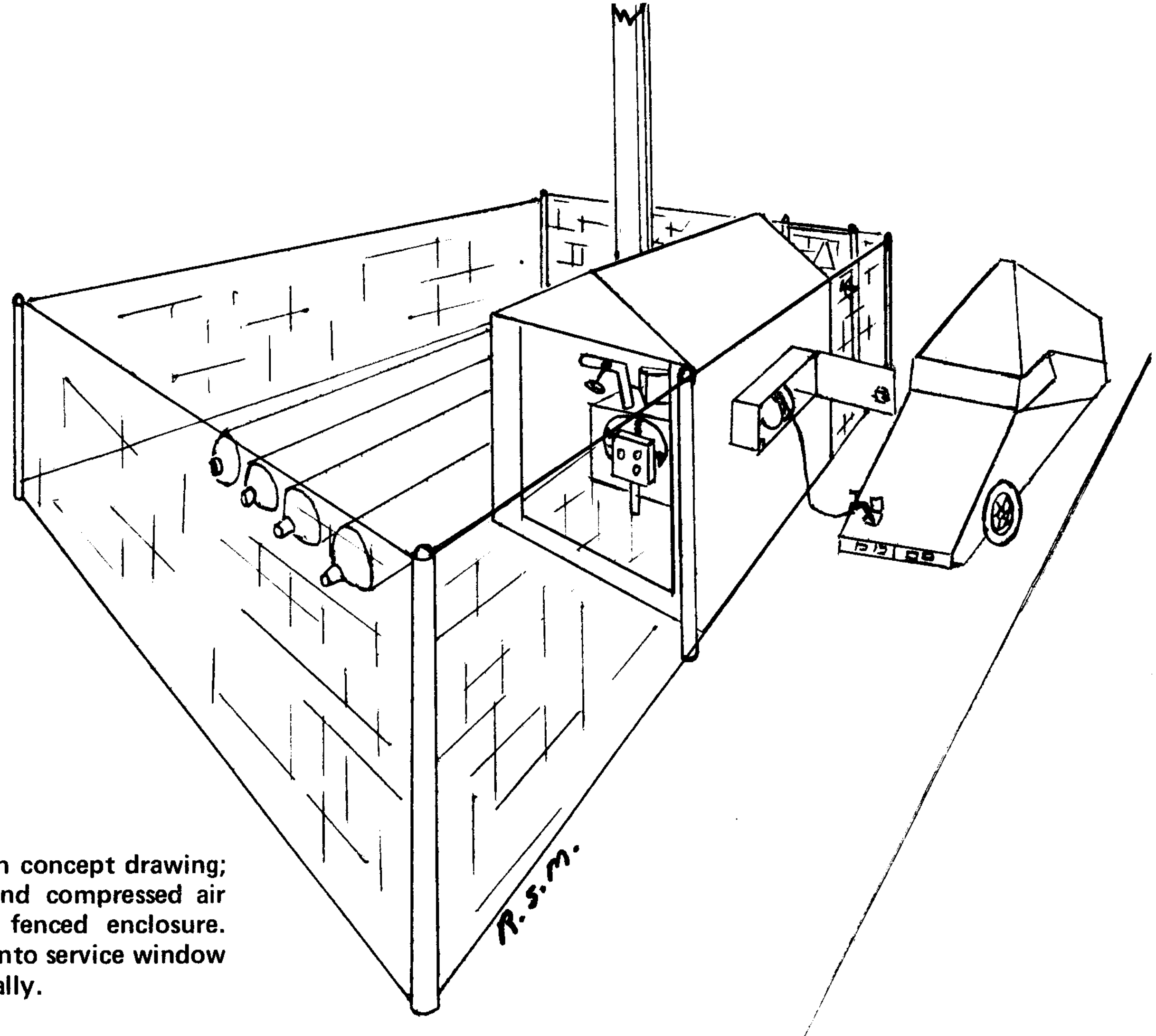
This general outline on raising the capital for an air station has not been proven workable yet. It does as a prime consideration provide for the reimbursement of (sponsors) investors without them having to actually (donate) spend money but rather invest money. I'm told the investment of money by the people and repayment by the people with interest is sound. It has come to my attention that schools are entitled to number one status in line for surplus government air compressors, tanks etc. Should a school in your area work to promote and set up an air station please help them all you can. The technology for quick-fill stations is already here. Utility companies have been using quick-fill stations to run service trucks on natural gas for several years. They use the same compressors, storage tanks and gas cylinders in the trucks as required for air cars. With funding an air station can be set-up in two weeks.

A neighborhood air station with several families investing and selling themselves air is workable.

A review of the bylaws of a local flying club can provide a good outline for air station bylaws.

A car club air station is workable. An air station set up by a manufacturer is workable. An air station set up as a profit making firm is not workable, as I see it.

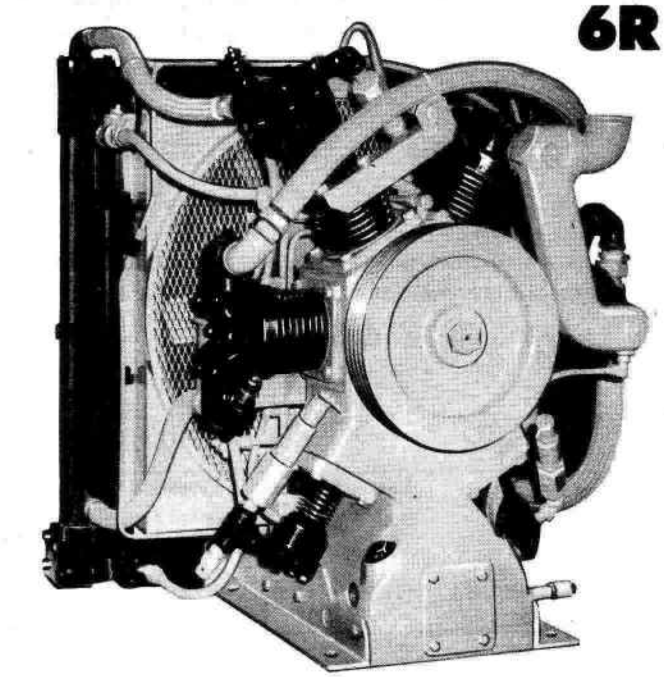
Consult a local attorney for legal counsel to do it right. Let me know when you set up an air station. I would love to be there for the ribbon cutting ceremony. Terry Miller



Self-Service Air Station concept drawing; compressor building and compressed air storage tanks within fenced enclosure. Airup Hose reels back into service window which locks automatically.

Ingersoll-Rand.

High Pressure-Air Cooled 6R Series Air Compressors



- **60 through 100 horsepower**
- **1000 to 6000 psig (68.95 to 413.7 bar) pressure**
- **Compact design—available either belt driven or direct connected to flange mounted motor**
- **Bare compressor available for custom applications**

Intake Filter—Oil bath inlet filter.

Frame—Cylinders and crankshaft with bearings are frame (crankcase) supported. The frame is of close grained cast iron, completely sealed against dirt to protect the running parts, and provides a large oil sump.

Crankshaft—Is one throw on the crankshaft utilizing a master and articulated rod set construction. This design provides excellent balance, minimum vibration and compactness.

Cylinders—Are separately cast and individually flange bolted to the frame. Cylinders are precision honed for compatibility with the piston rings and employ deep radial fins to help remove the heat of compression.

Flywheel—Cooling is accomplished by a 6-bladed fan mounted on the end of the compressor crankshaft opposite the drive end. Cooling air is first pulled over the finned tube intercoolers and aftercooler, which are in a single radiator assembly completely piped, and then blown over the compressor's finned cylinders and frame.

Intercoolers—Are of finned tube construction and are provided with safety valves.

Lubrication—A vane-type oil pump draws oil from the crankcase and completely lubricates all moving parts. The oil is filtered through an outside accessible full-flow filter. The crankcase breather is piped to inlet.

Valves—Dual channel valves are used in the first and second stages, and dual K-type plate valves are used in the 3rd, 4th, and 5th stages.

Unloading—Automatic starting unloading.

Base—Is of heavy steel construction with provision for motor movement to facilitate "V" belt adjustment on belt driven units.

Regulation—These machines are normally provided less regulation. All models are available with auto start and stop control and constant speed control or dual control.

Belt Guard—Belt guards are available as accessory equipment. Totally enclosed guards provide protection on all sides.

Aftercooler — Air-cooled, finned-tube radiator type, with inter-connecting piping and support base. The aftercooler has 25°F (—4°C) CTD when new.

Safety Protective Devices—These are chosen to protect the compressor. Customer must supply special items when other than standard.

STANDARD EQUIPMENT

- Oil bath inlet filter.
- Force-feed lubrication with full-flow filter.
- Air-cooled, radiator type intercoolers, aftercooler and inter-connecting piping and support base.
- Moisture separator and trap after each cooler.
- Automatic condensate drainage of each separator trap.
- Automatic starting unloading.
- Panel mounted interstage, discharge and oil pressure gages.
- Mounted (general purpose enclosure) pressure switch for low oil pressure shut down. Any other switches are not mounted.
- Safety valves on first four stages with shear disc valve on fifth stage.

ACCESSORIES

- Automatic start and stop control, including time delay relay (not mounted)*
- Constant-Speed control (auxiliary valve not mounted)
- Dual control, including time delay relay (electrical components not mounted)*
- Totally enclosed Belt Guard

*Time delay relay is required with low oil pressure shut down for motor driven units. Specify control circuit when ordering even if same as motor voltage.

MODEL DESIGNATION

Bare Compressor	V-Belt Drive Base Plate Mounted	Direct-Connected by Flexible Coupling to Flange Mounted Motor
6R80	6R80X	6R80MX
6R100	6R100X	6R100MX
6R80-100	6R80-100X	6R80-100MX

PERFORMANCE DATA

Max. Disch. psig (bar)	PD CFM (m³/min)	RPM	Model	1000 psig (68.95 bar)		1500 psig (103.42 bar)		2000 psig (137.9 bar)		3000 psig (206.85 bar)		4000 psig (275.8 bar)		5000 psig (344.75 bar)		6000 psig (413.7 bar)	
				ACFM (m³/min)	BHP	ACFM (m³/min)	BHP	ACFM (m³/min)	BHP	ACFM (m³/min)	BHP	ACFM (m³/min)	BHP	ACFM (m³/min)	BHP	ACFM (m³/min)	BHP
6000 (413.7)	122.7 (3.45)	1800	6R80							83 (2.4)	65.1	82 (2.3)	68.3	81.0 (2.28)	69.8	80.0 (2.26)	71.4
2000 (137.9)	148.0 (4.2)	1800	6R100	105 (3.0)	68.3	102 (2.9)	71.4	100 (2.8)	73.5								
6000 (413.7)	148.0 (4.2)	1800	6R80-100							103 (2.92)	78.8	102 (2.9)	81.4	100 (2.83)	83.0	99 (2.8)	87.2

Note: Deduct 5% to BHP figures for direct connected units.
The 6R Series Compressors can be operated at a minimum of 1200 RPM.
For Altitude Performance use:
BHP Correction Factor 1% decrease for each 1000 ft. (304.8 m) above SL.
ACFM Correction Factor 0.533% decrease for each 1000 ft. (304.8 m) above SL.

ENGINEERING DATA

Model	Max. Discharge Pressure		Cylinders				RPM		Pipe Size		V-Belt Wheel		
			Bore		Stroke				Inlet	Discharge	OD		No. and Size Grooves
	psig	bar	inches	mm	in.	mm	Min.	Max.	in.	in.	in.	mm	
6R80	6000	413.7	5 & 5 & 3⅝ & 1⅞ & 1 & ⅝	127 & 127 & 92.1 & 47.6 & 25.4 & 15.8	3	76.2	1200	1800	2½	¼	12⅛	308	6-5V
6R100	2000	137.9	5½ & 5½ & 3¼ & 3¼ & 1⅞ & 1	139.7 & 139.7 & 82.5 & 82.5 & 47.6 & 25.4	3	76.2	1200	1800	2½	¼	12⅛	308	6-5V
6R80-100	6000	413.7	5½ & 5½ & 3⅝ & 1⅞ & 1 & ⅝	139.7 & 139.7 & 92.1 & 47.6 & 25.4 & 15.8	3	76.2	1200	1800	2½	¼	12⅛	308	6-5V

WEIGHTS

Model	Baseplate Mounted with Motor						Bare					
	Net		Domestic		Export		Net		Domestic		Export	
	lb	kg	lb	kg	lb	kg	lb	kg	lb	kg	lb	kg
ALL	3200	1451	3550	1610	3650	1655	1530	694	1790	812	1850	839

Note: Weights may vary on 6R Series Compressors.

Ingersoll-Rand
TYPE 30 COMPRESSOR DIVISION
CAMPBELLSVILLE, KY. 42718

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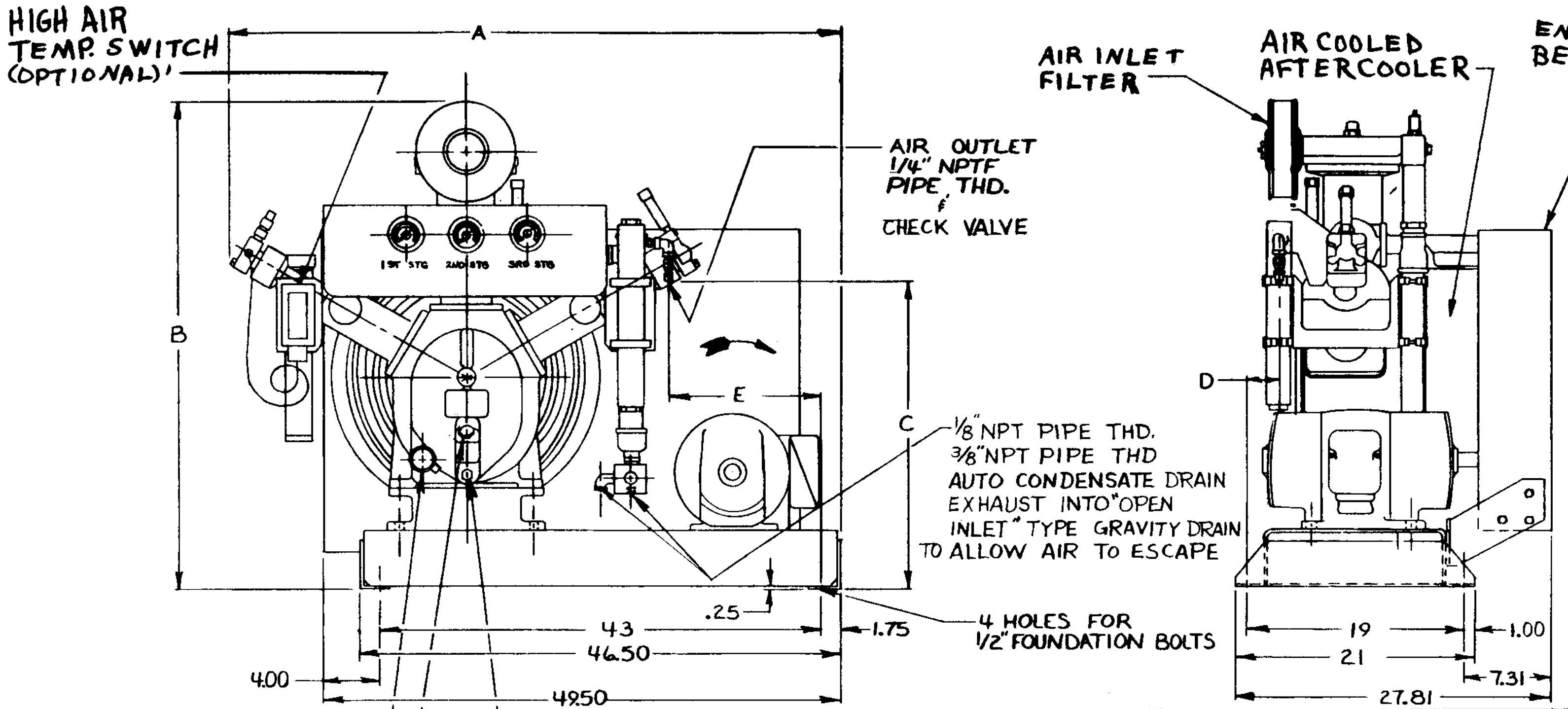
Printed in U.S.A.

FORM SCD-211A
SEPTEMBER 1979

Ingersoll-Rand
Small Compressor Division

Industrial Park, Campbellsville, Kentucky 42718
502-465-3511

SCD-211A



SYMBOL	APPROX NET.WT. LBS.	DIMENSIONS GIVEN IN INCHES						
		A	B	C	D	E	F	G
10T2X9, H10T2X9, 10T2X, H10T2X	925	57.25	40.75	24.25	1.94	17.69		
15T4X15, H15T4X15, 15T4X20, H15T4X20	1145	57.75	42.88	26.75	1.69	16.50		

APPROVED FOR

1-R ORDER NO.	DISCHARGE PRESSURE PSIG:	JOB:
CUSTOMER:	ACTUAL DELIVERY-CFM-FREE AIR	SPECS:
CUST. ORDER NO.	REGUL. AS&S CSC DUAL CONTROL	ITEM:
PER: DATE:	MOTOR-HORSE POWER	ARCH/ENG.:
SIZE	MOTOR-ENCLOSURE	CONTRACTOR:
MODEL	MOTOR-VOLTS. PH. HZ.	
PISTON DISPLACEMENT-CFM	STARTER-TYPE	
SPEED-R.P.M.	HIGH AIR TEMP. SWITCH YES NO	

NOTES:
1. FOUNDATION OR FLOOR MUST BE LEVEL AND SUPPORT ALL FEET EQUALLY; IF NECESSARY SHIM OR GROUT THE FOURTH FOOT.
2. THE COMPRESSOR ARRANGEMENT SHOWN IS REPRESENTATIVE OF ALL THE UNITS LISTED. SPECIFIED ACCESSORY ITEMS ARE NOT NECESSARILY SHOWN BUT WILL NOT INCREASE THE DIMENSIONS UNLESS OTHERWISE SPECIFIED.
3. FOUNDATION BOLTS SHOULD PROJECT THRU NUTS AT LEAST 1/2" TO ALLOW FOR LEVELING.
4. ALLOW AT LEAST 12" CLEARANCE ON ALL SIDES FOR PROPER AIR CIRCULATION.
5. INTERSTAGE AND DISCHARGE CONNECTIONS PROTECTED BY SAFETY VALVES.

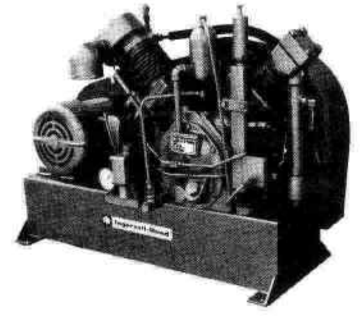
INGERSOLL-RAND COMPANY
CAMPBELLSVILLE, KY. 42718

OUTLINE AND GENERAL ARRANGEMENT
BASEPLATE MOUNTED
TYPE 30 AIR COMPRESSORS

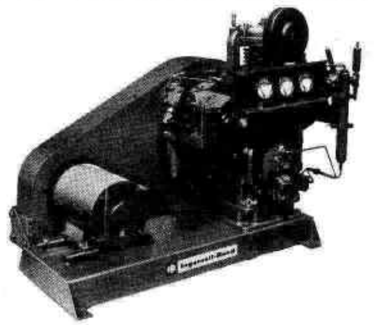
DATE: 9-21-78
H48092

High Pressure Air-Cooled Air Compressors

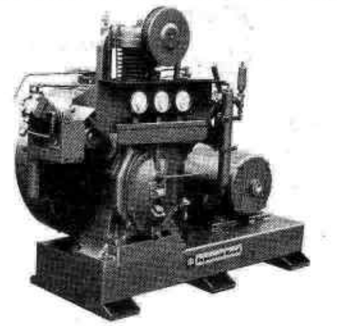
From Ingersoll-Rand's Small Compressor Division



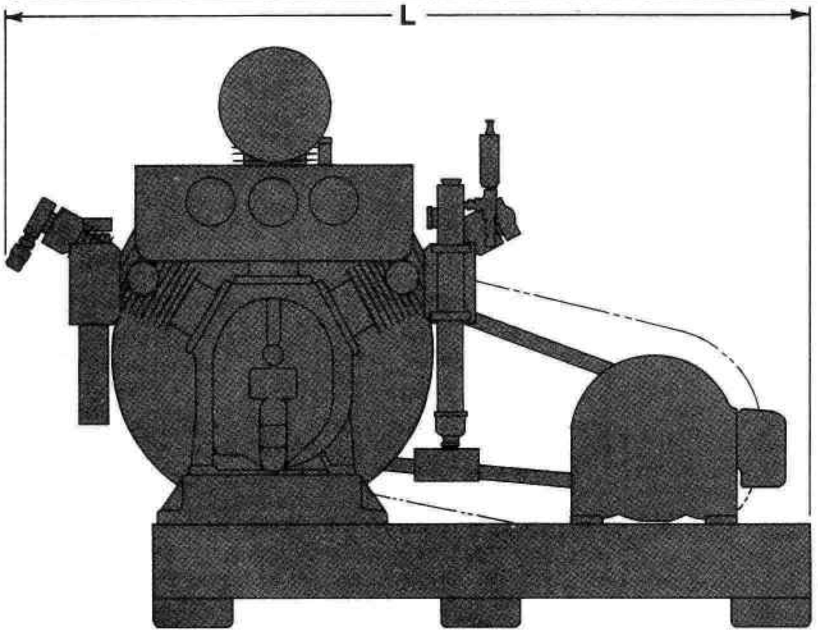
Model 223 is a 5 Hp, three-stage unit rated at 3000 Psig maximum pressure.

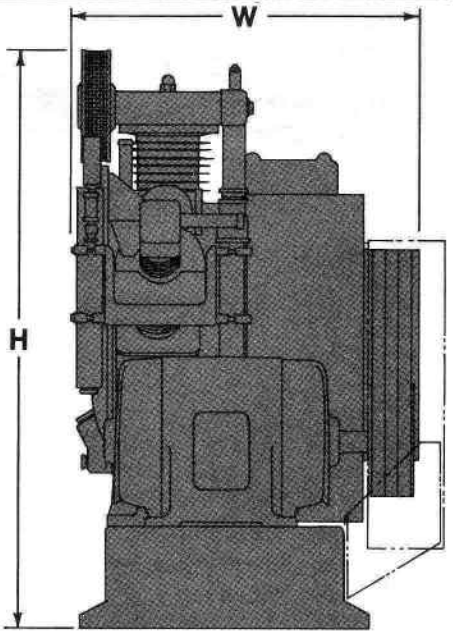


Model 10T2 is a four-stage, 10 or 15 Hp unit rated at 3500 Psig maximum pressure. Models also available for 5000 Psig.



Model 15T4 is a four-stage, 20 Hp unit rated at 3500 Psig maximum pressure. Models also available for 5000 Psig.





- High pressure bottle charging for industry, civil defense and municipalities

ENGINEERING DATA

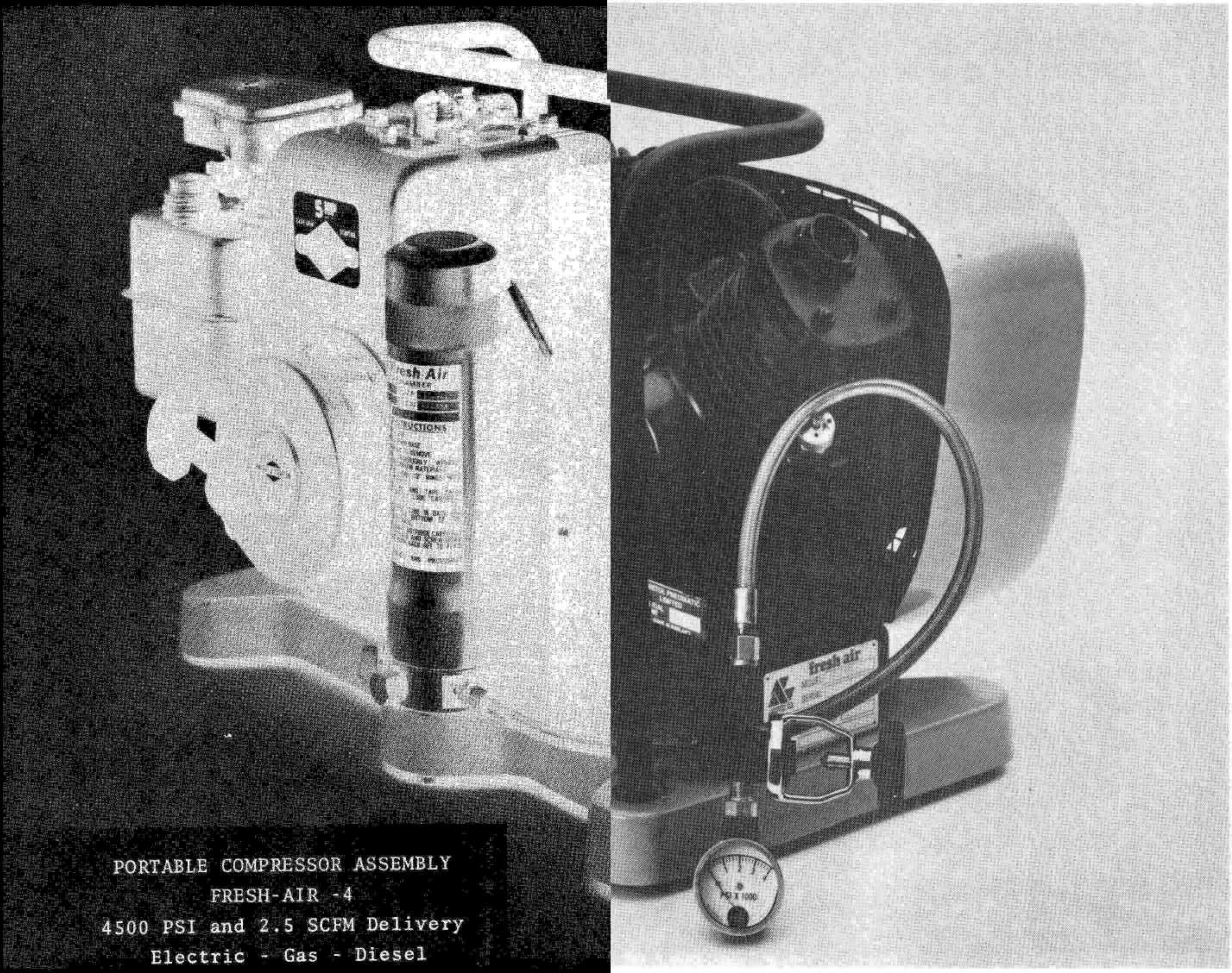
Max Press		P.D.		Motor Rating		Model	RPM	Dimensions						Weights			
								Length		Width		Height		Bare		Base Mtd	
Psig	bar	cfm	m³/min	Hp	kW			in	mm	in	mm	in	mm	lbs	kg	lbs	kg
3000	207	11.0	0.31	5	3.7	223	985	42.0	1067	21.5	546	28.0	711	310	141	500	227
3500	207	22.0	0.62	10	7.5	10T2	860	58.5	1486	26.0	660	40.2	1021	695	315	925	420
3500	207	25.6	0.72	15	11.2	10T2	1000	58.5	1486	26.0	660	40.2	1021	695	315	975	442
3500	207	36.8	1.04	20	14.9	15T4	1000	58.4	1483	27.0	686	45.5	1156	780	354	1145	519
5000	345	20.4	0.58	10	7.5	H10T2	800	58.5	1486	26.0	660	40.2	1021	695	315	925	420
5000	345	25.6	0.72	15	11.2	H10T2	1000	58.5	1486	26.0	660	40.2	1021	695	315	975	442
5000	345	32.7	0.93	15	11.2	H15T4	890	58.4	1483	27.0	686	45.5	1156	780	354	1050	476
5000	345	36.8	1.04	20	14.9	H15T4	1000	58.4	1483	27.0	686	45.5	1156	780	354	1145	519

2 to 20 Hp, 300 to 5000 Psig (20.6 to 345 bar)

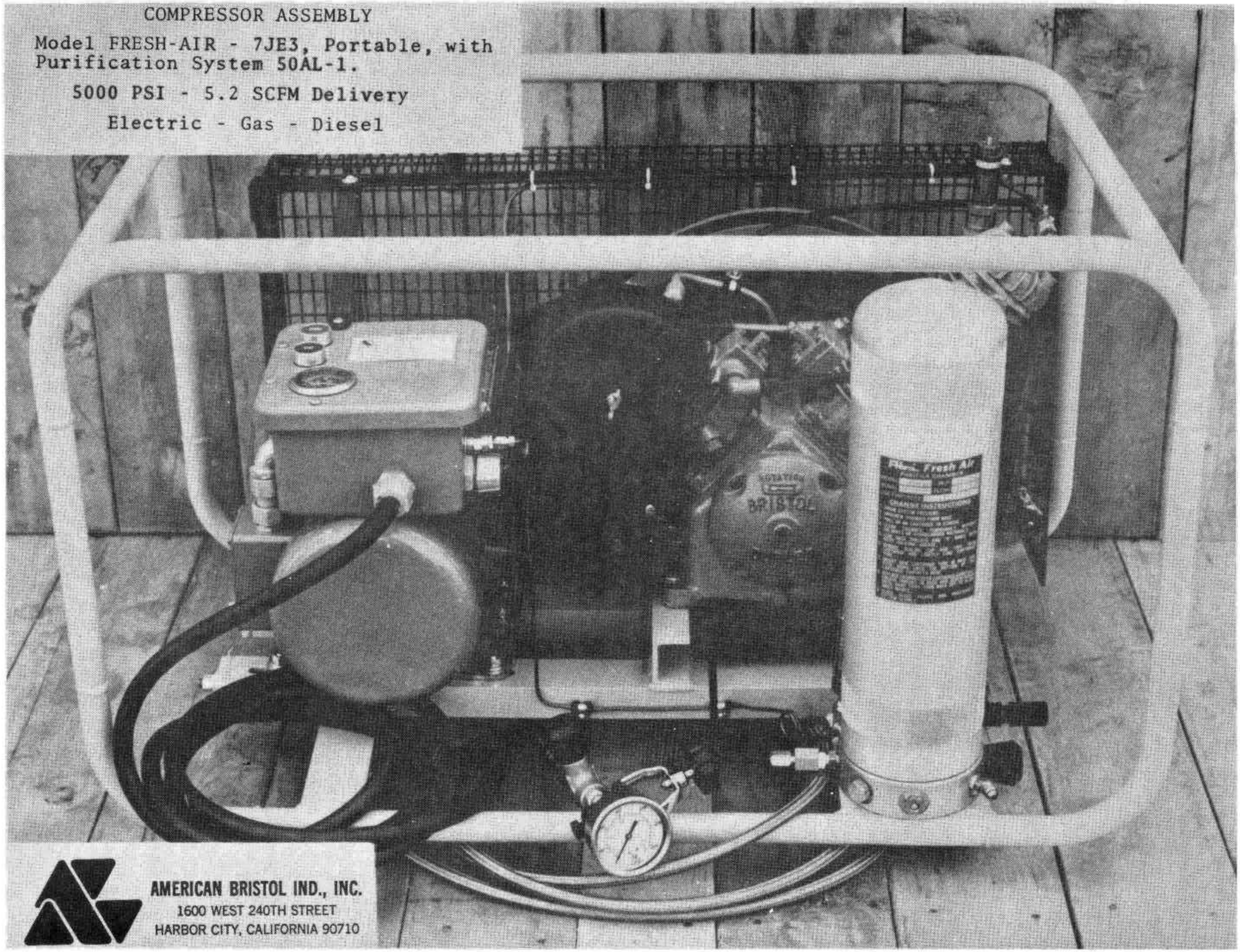
Ingersoll-Rand offers a complete line of heavy-duty industrial Type 30 compressors, designed specifically for high pressure operation.

Compressor frames have large oil capacity to assure low bearing temperatures and adequate lubrication for long periods.

Valves are made of materials which resist the corrosive condensate which forms naturally when compressing air to high pressures. Carbon deposit on valves is limited by careful control of amount of oil used to lubricate cylinders. Rings are of special design, of sufficient number and arrangement, and are fitted to cylinder wall.



PORTABLE COMPRESSOR ASSEMBLY
FRESH-AIR -4
4500 PSI and 2.5 SCFM Delivery
Electric - Gas - Diesel



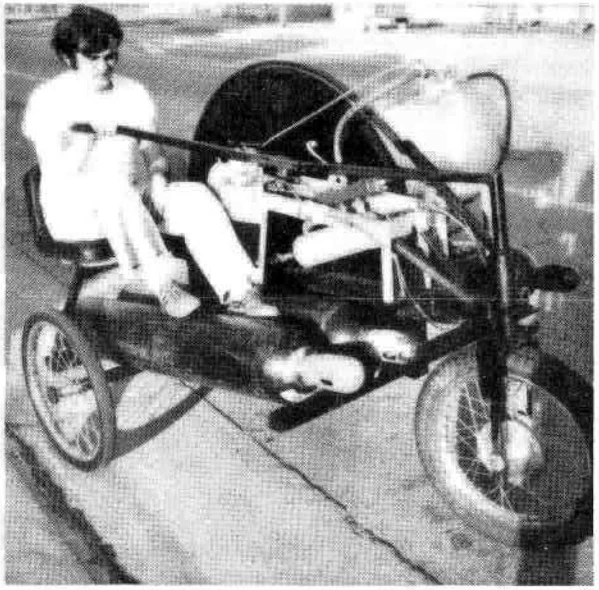
COMPRESSOR ASSEMBLY

Model FRESH-AIR - 7JE3, Portable, with Purification System 50AL-1.

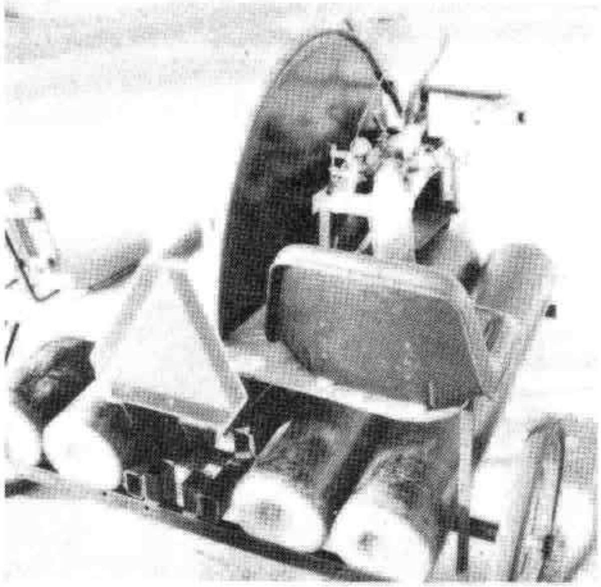
5000 PSI - 5.2 SCFM Delivery

Electric - Gas - Diesel

AMERICAN BRISTOL IND., INC.
1600 WEST 240TH STREET
HARBOR CITY, CALIFORNIA 90710

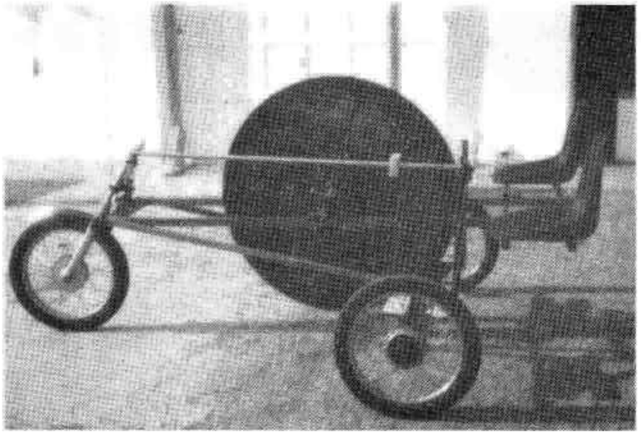


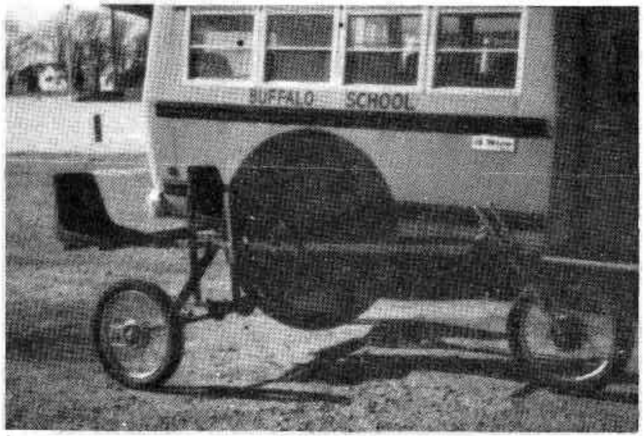
Snapshot of Mike Samuels, my stepson, on air car 1. She can now carry four "T" size cylinders. Installed a stronger axle 1 15/16" dia. car weight with 4 cylinders approximately 1,400 lbs. It could be 900 lbs.

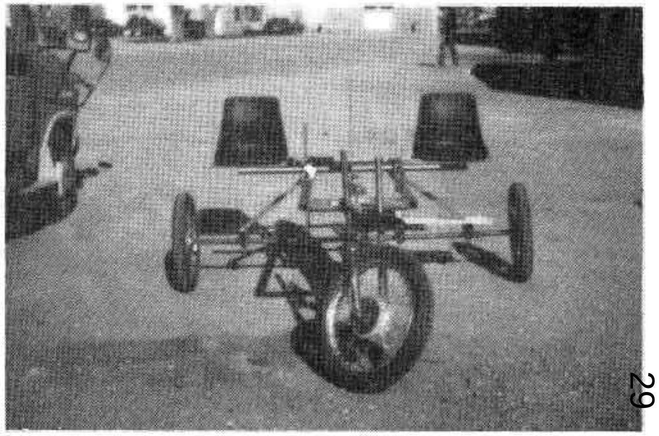


With 1,320 cu. ft. of air, in town shopping range has increased considerably. Driven with 4 tanks Dec. 21st 1979.

AIR CAR 1-A NEARING COMPLETION - Dateline! Buffalo, Oklahoma - At this city located near the panhandle of Oklahoma, five Physics students are near completion of a project started Nov. 11th this year. Their car to be powered by air is claiming attention and letters of support from residents in Oklahoma and other states. Their instructor, Gwen Cook says, "Mr. Miller's air car design has made it possible for my students to deal first hand with a positive step toward solving our energy problem. It has not only provided an opportunity to apply classroom Physics, but also a chance to attack our fuel problem actively and creatively. I feel we are very fortunate to be allowed to work and experience the difficulty and reward of building an air car." Tulsa and Oklahoma City papers have kept Oklahomians informed of their progress. Buffalo High School is picking up half the cost with the students paying the rest. You may wish to let your own local news media know about the students and their project. Your local high school Principle may wish to contact Buffalo High School to inquire of their progress and ask for a report from the students on completion of their testing.



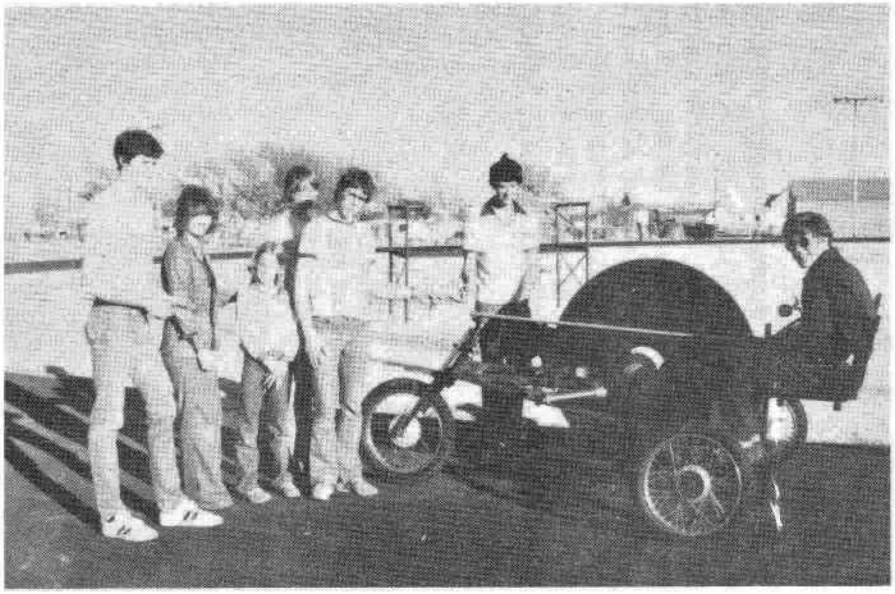


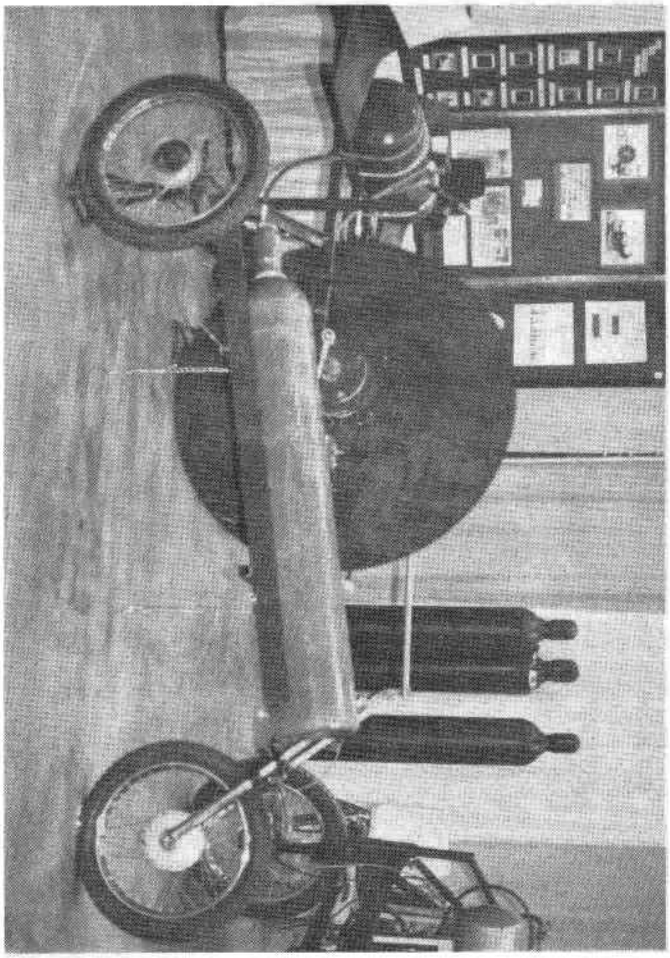


AIR CAR 1A ROAD TESTED

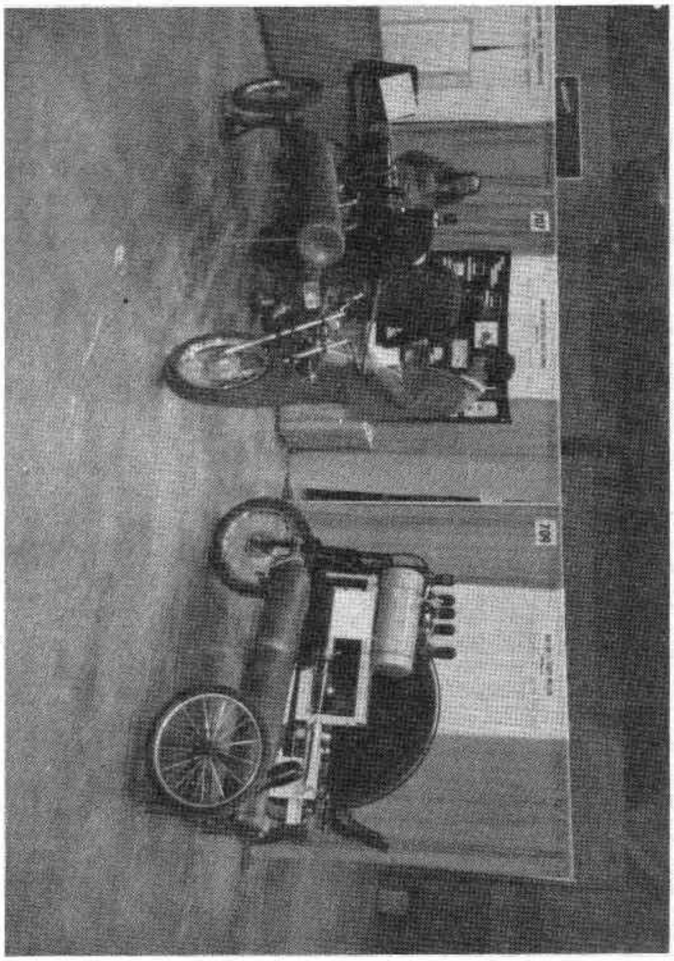
BUFFALO, OKLAHOMA

Five students, Ronnie Catlin, John Holcomb, Robert Holcomb, Lonnie McManus and David Yauk road tested Air Car 1-A with two actuating cylinders in February of 1980. They showed their car in Kansas City and Oklahoma City at the Energy Expositions there in March and April. Their instructor Gwen Cook is assisting them in exploring grants which may be available to finance further development. They wish to build a car with three actuating cylinders arranged in a radial configuration. Ronnie Catlin a junior in 1980 will have another year in high school to work with other high school students in further design and testing. Gwen Cook says their car cruises at 33 m.p.h. Curb weight of car with one air tank is 550 pounds. Gwen Cook and her class figure a third actuating cylinder will give the car more than ample power so more air tanks can be carried to increase range.





Student's Air Car 1-A at energy exposition in Kansas City



Terry Miller's Air Car 1

The Joplin Globe

Joplin, Missouri, Saturday, October 6, 1979—Twenty-Six Pages

SUGGESTED PRICE
Daily 20c—Sunday 50c

Inventor Displays Air-Powered Vehicle

By BRIAN HUTTON
Globe Staff Writer

CRESTLINE, Kan. — It may or may not be the answer to the nation's energy problems, but it does run.

Air Car One, a prototype compressed-air-powered vehicle manuvered successfully through its first public debut here at 2 p.m. Friday, under the proud eyes of inventor Terry Miller, 45, Crestline.

Miller's stepson, Mike Samuels, was the first to drive the new idea. After pushing the car out of the garage onto Kansas Highway 69, he climbed into the drivers seat and turned on two valves. The car hesitated a moment but then slowly the 45-inch main gear began to turn, powering the car down the road.

The car continued down the road a half-mile before Samuels turned it around, bringing it back to the garage and offering "the wheel" to the more than 30 newsmen and interested people who had gathered to view the event.

According to Miller, the biggest advantage of his new invention is its affordability. "Anyone can build one of these cars," he said. "And I'll help anyone that wants to build one to the best of my ability."

Air Car One was concieved and built in a total of 16 weeks. Miller explained that the idea for the car came after he failed in his attempt to build a spring-powered car. "I couldn't find any springs large enough to provide enough power," he said, explaining that difficulty with an air wrench led to his work on the air-powered car.

He began work on the car in mid-May, conducting his first test run on July 19. By Friday he had also completed work on a special pump he uses to fill the commercial air tank used on the car.

"All of the parts on this car," he boasts, "are over-the-counter products available from hardware supply stores, welding supplies stores, and even some from farm supply stores."

Miller estimated the total cost of his prototype at $884, but that includes more than $300 to have welding and machine work done, and another $165 for the tank. The tanks, he noted, can be leased for about $20 a year from most welding supply companies.

Top speed of Air Car One so far has been 32 miles an hour, but that Miller explains, is because the car is actually built out of a workbench. "We built it on a workbench," he explained, "but it worked so well when we tested it, we just took the legs off the workbench and put on wheels rather than build a body for this first one."

By changing the smaller gears on the axles, and thus the gear ratio, Miller believes the car can go much faster. "If someone wants a car that has a top speed of 65 miles per hour, with an economy speed of 35, then he can build one. He also told one reporter that he would build a car that goes 60 mph, "if you'll ride in it."

The best distance for the new car was a trip to Baxter Springs, a little over nine miles. Distance is a problem, he told the crowd, explaining that the added weight of a larger tank, or of more tanks, would help to cut down the mileage. He estimated future air cars would have to remain under 700 pounds to be efficient.

For a mass production car, Miller would add an electric generator, solving three problems. The generator would allow the car to be equipped with reverse, would help on steep inclines, and would allow the car to start moving quick enough to move into traffic.

The prototype currently starts very slowly, and builds up speed slowly. Toward the end of the "free-rides session", as the tank emptied, the car had to be pushed a couple of times to help get it rolling.

Miller, who moved to Crestline six years ago and now operates Sharon Enterprise, a company named after his wife and which constructs camper tops, is a graduate of the Spartan School of Aeronautics, Tulsa, Okla. and a licensed aircraft mechanic.

Once before he offered nationally a product he had designed, "Sweet 16," which at the time was the largest model aircraft available commercially. About 1,600 of the planes were sold before they were taken off the market.

Miller said he does intend to apply for a patent for his compressed air car within a year, but only to help insure standardization and safety of the vehicle. The plans are available free to anyone who want them, he said, by writing to him. Any commercial manufacturers that was interested could build the car for only a $10 royalty per unit, he said.

The Morning Sun

(USPS -434-180)

Pittsburg, Kansas, Saturday, October 6, 1979—30 Pages, 3 Sections.

Crestline man unveils invention: car that runs on compressed air

By LAUREL WOLKEY
Morning Sun Staff Writer

CRESTLINE — If Americans began following Terry Miller's example, the price of gasoline at the pump would no longer be a worry. Miller, who designed a three-wheeled car that is fueled on compressed air, revealed his invention to the public Friday in Crestline.

The small group of onlookers who had gathered in front of a building where the car was housed, may have been skeptical, but were soon taking turns riding in the two-seater car. Miller's stepson, Mike Samuels, began picking up passengers for short rides down the main street of the town.

Miller distributed an instruction manual detailing the air-powered system and announced that the design and information needed to build such a car would be made available to "anyone who wants to use it."

In the manual Miller stated,"I hereby give my permission for anyone to build their own air car. In making this knowledge public, I am foregoing any foreign patents."

However, Miller said he would seek a U.S. patent on one valve he designed and would request $10.00 for each of these valves used by commercial car builders. "In return, I shall help promote air cars and give of my knowledge to those building air cars for private use or for profit," he said.

The car, which Miller referred to as "Air Car I," was made entirely of simple hardware parts that are available in most supply stores. Miller claimed that anyone could build a similar air car for about $850.

Miller, owner of Sharon Enterprises in Crestline, said his research and design of the air car began 16 weeks ago. Along with the car, Miller built his own air pump to compress the air into cylinders that are then used to power the car.

According to Miller, the only new concept that distinguishes his car from other experiments with air-fueled autos, lies in the valve that he hopes to patent. Although he does not yet have the patent, Miller said he wanted to share his invention with the public.

"To keep my air car successes a secret for a few years during patent processes and while negotiating with some big money corporation in hopes of getting rich, would turn me off," Miller said Tuesday.

The Air Car I is designed to run on medium pressure air, a combination of 19.5 percent oxygen and 80.5 percent nitrogen. Medium pressure air differs from breathing air in that it contains some oil, Miller said earlier this week.

Miller said that although his car travels comfortably at only 32 miles per hour or less, the air pressure can be adjusted for a greater speed in other cars.

"I can show anyone how to get any speed they want. There is no limit to the amount of air pressure you can use," he said.

One kink that has not been worked out of the new fuel use, Miller said, is the distance that an air car can travel before refueling. The Air Car I has only enough room for two air cylinders and can travel less than 10 miles before refueling.

However, Miller said that the problem could be solved by building larger cars with more air cylinders. Miller said that he plans to build a larger 13 foot air car that seats four people.

Miller said Tuesday that if the concept of air powered cars catches on, "air stations" instead of gas stations could easily and economically be established with the use of large air pumps. An air-fueled car similar to the one he designed would cost less than two cents a mile to run, he said.

Coffeyville, Kan. Journal Sunday, January 6, 1980

Idea for air car travels faster than expected

By JACK HUTTIG
Staff Writer

Good ideas travel fast.

Some travel faster than others.

But even inventor Terry Miller was surprised at the speed with which five high school students from Buffalo, Okla., picked up on his compressed air-powered automobile and built their own version.

"I could believe an aeronautical engineer or an auto mechanic building the first one," Miller said Saturday, "But five high school kids?"

The students — seniors John and Robert Holcomb, Lonnie McManus and Paul Yauk and junior Ronnie Catlin — and science instructor Gwen Cook displayed Air Car 1A to Miller Saturday afternoon on the main highway through Crestline. Miller, the inventor of Air Car 1 who provided the quintet with the plans on which their design was based, was impressed with the result.

Although Air Car 1A has only one piston-driving air cylinder compared with two cylinders on Air Car 1, it's much lighter and just as fast. The students plan to add a second cylinder as soon as they can scrap together the time and money.

"Right now, the exhaust is escaping into the atmosphere," John Holcomb explained. "When we get the second cylinder, the exhaust air from the first cylinder will feed into a second and power it." Unlike an automobile, adding cylinders will improve the vehicle's "mileage" as well as its speed, he explained.

Compressed air from a tank is fed into the driving cylinder at 250 pounds per square inch (psi) through a timing valve, Holcomb explained. Air expands inside the cylinder, driving a rod forward which pushes a cam. The cam revolves, driving a huge gear which meshes with a smaller gear which turns an axel and drives the tricycle-like vehicle's two rear wheels.

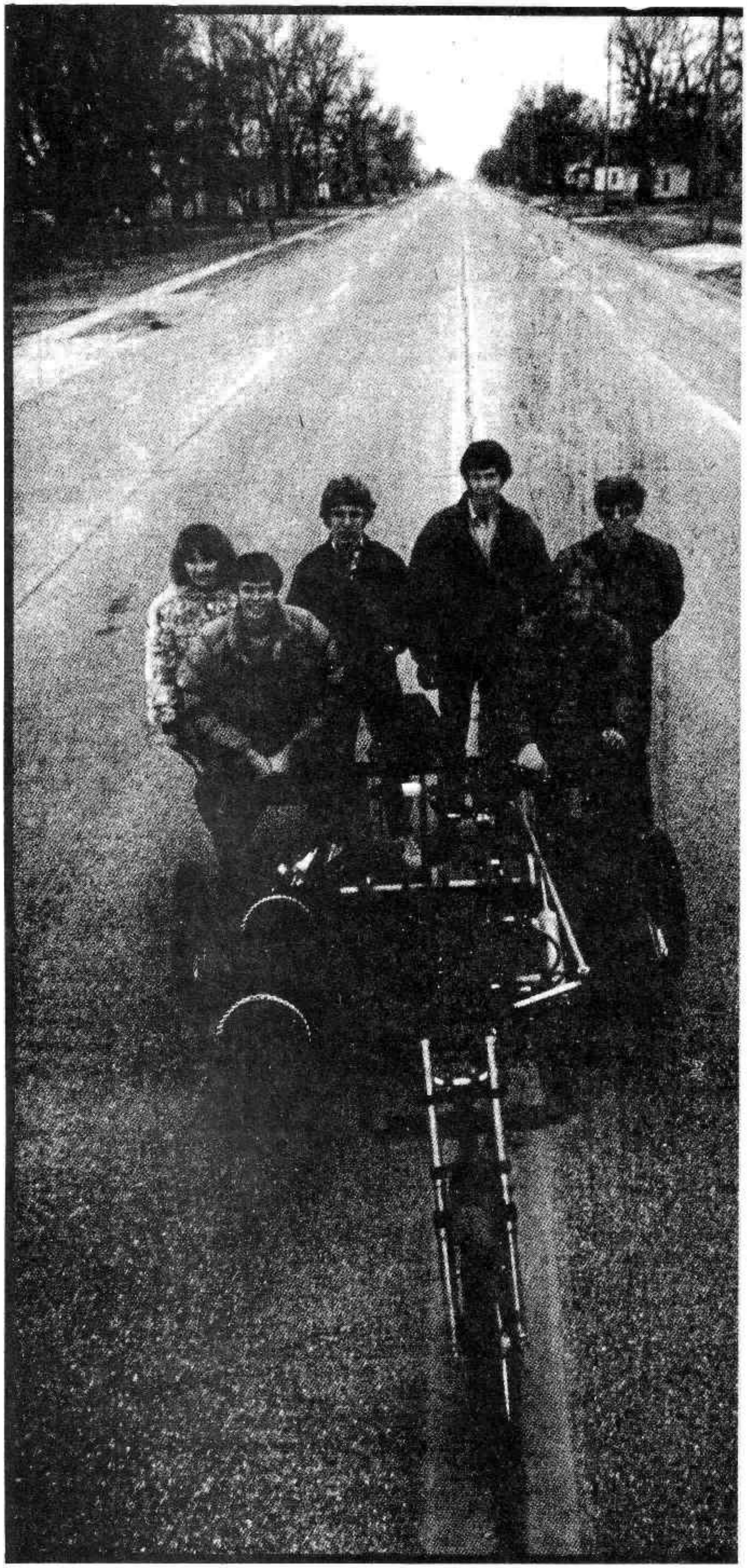
Compressed air exhausted from the first cylinder can be stored in a holding tank, then released moments later through another timing valve to power a second cylinder. Miller speculates up to six cylinders could be hooked together to form a radial engine.

"With a second cylinder, we can go twice as far at twice the speed," Holcomb said.

Air Car 1A will go 6.3 miles on 300 cubic feet of compressed air, Holcomb said. (Electricity to fill a tank with that much compressed air costs 10½ cents, Miller said.) As gasoline prices continue to rise, the air car will gain widespread use for in-town travel, he predicted.

Miller, rather than resent the competition, has helped any would-be air car builders who have approached him. Although he's seeking a patent for the car, he's given away thousands of copies of the plans to promote the idea.

"If you come here," science instructor Mrs. Cook said, "he'll even take you to get the parts."



The Chanute Tribune

CHANUTE, KANSAS, 66720, MONDAY, JANUARY 7, 1980

Energy-saving car not just hot air

By DON MUNDAY

CRESTLINE - Spectators watched, drivers gawked, and five high school students savored the limelight as the little town of Crestline saw not one air-powered car driving down its main street Saturday, but two.

Gwen Cook, a science teacher from Buffalo High School, Buffalo, Okla., and her physics class had brought an air car of their own construction to Crestline to show to the car's inventor, Terry Miller.

"Really, we've just got our foot in the door on this whole thing," Cook said as her students explained their machine to interested spectators and a small flock of reporters.

Four BHS seniors, Paul Yauk, Lonnie McManus and John and Robert Holcomb, along with junior Ron Catlin, had trucked to their version of Miller's car, which he unveiled in October.

Cook had seen Miller's invention, Air Car 1, at an energy exposition in Wichita and told the class about it. They were fascinated by the idea of a car that ran on compressed air — fascinated enough to build one of their own.

The student's version, which was dubbed Air Car 1A, was based on Miller's design but with modifications in the propulsion system.

"Ours is lighter, with three more teeth on the main gear, and with a two-passenger capacity," one of the students said.

Examining the student's car and comparing it with his own, Miller said, "These kids are doing two passengers on only one cylinder. I never did that. They'll break my speed record for one cylinder easily."

The students were as eager to see their car perform as Miller was.

"We've never really given it a full tryout," one student said. "We've run it to see if the engine worked, but we haven't had a chance to road-test it."

The five pushed their car out onto K-26, which serves as Crestline's main street, and Yauk, the Orville Wright of the group, eased into the driver's seat. The others huddled around their machine, adjusting the pressure gauges in preparation for the initial run.

When all systems looked right to the students, they gave Air Car 1A a push and Yauk was on his way.

Moving along at a leisurely pace, the car periodically emitted a loud hiss as air was released to run the gears. In between bursts of air, the car coasted along.

"It doesn't move in a uniform motion," Cook said. "It's not running on a steady power state right now."

They plan to add a second cylinder soon, she said. That would allow one cylinder to be compressing while the other was taking in air, giving the car a less abrupt movement.

Yauk drove Air Car 1A about 300 feet down the highway and made a graceful turn back to the garage.

Carefully watching the hissing machine, Miller said, "My car never went that fast on one cylinder. I'm jealous."

The students, who tended to talk all at once about their car, said that running the machine was easy and inexpensive.

Although drawing comparisons between Air Car 1A and an automobile was difficult because the car ran solely on compressed air, they estimated that their car would cost about 2 cents a mile to run. To fill the air tank strapped to the car required about 10 cents of electricity, which they noted could easily be produced by a windmill.

Inevitably, the students suggested a race between the two vehicles.

"I'll accept your challenge to a drag race," Miller said, "but I know right now you'll beat me."

Driving Miller's car in the race was Mike Samuels, wearing a T-shirt which proclaimed "Air Car No. 1." He moved the original into position next to the students' car and the informal drag race began.

Neither car could be declared a clear winner because no definite finish line had been decided upon. Instead, the pair of cars sputtered down the highway, turned in tandem and returned. Miller's car reached the garage first, probably because of the greater number of cylinders the more advanced model had.

The school paid for about half of the $800 required to build the machine. The students raised the other half through concession sales and fund drives, Cook said.

The students tried repeatedly to get Miller into the seat of Air Car 1A, but when he saw their steering system was different than his, he backed down.

"I'm a tiller man myself," he said. "I'm not going to drive it if it isn't steered by a tiller."

The students said they had spent about 300 hours since Nov. 17 working on the car after obtaining Miller's design.

Cook said she would give them an "A" grade on the project. She thought a moment, then added, "No, make that an 'A plus.'"

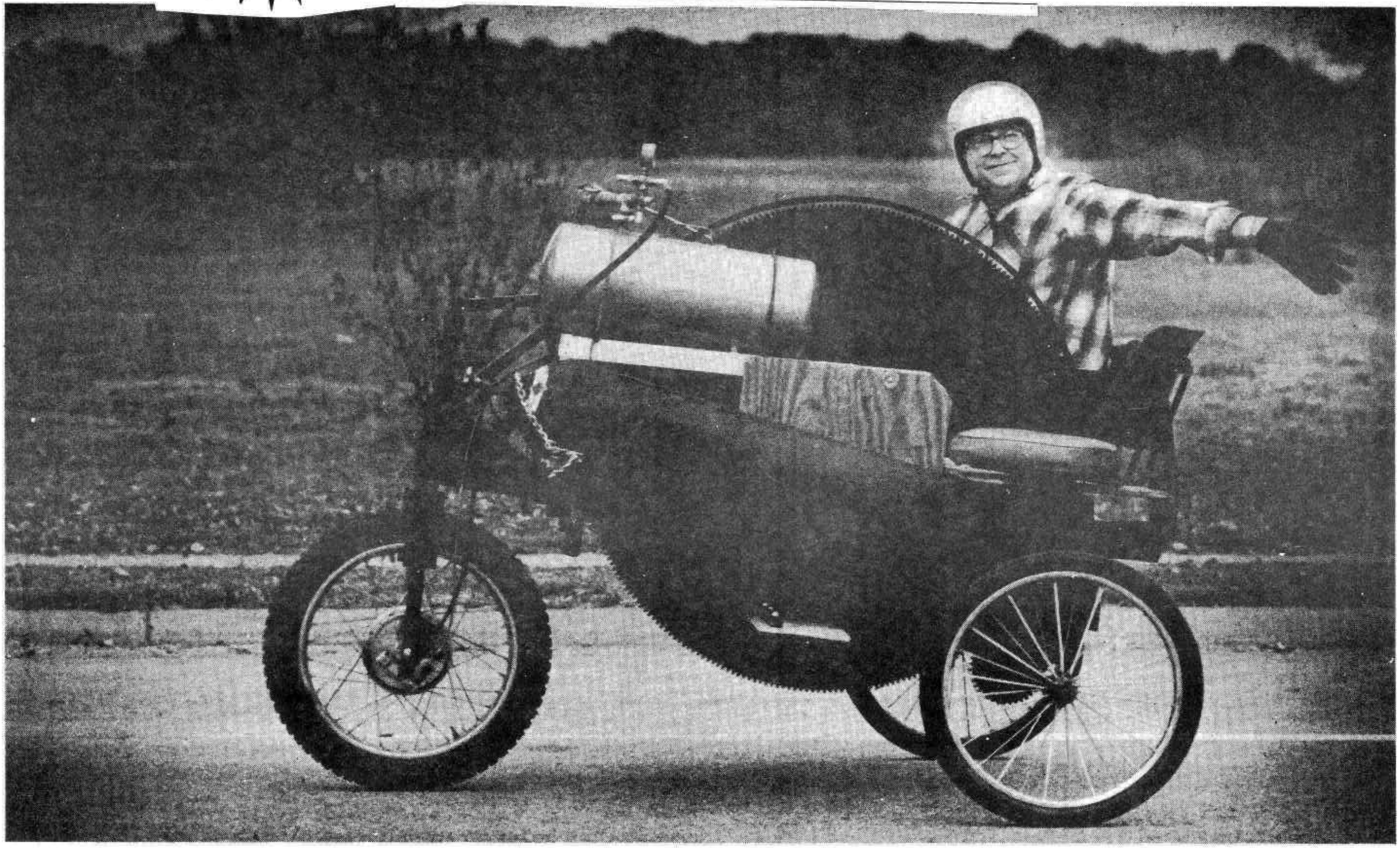
The students are convinced the air car is a realistic alternative to current forms of transportation.

"Sure, people laugh at it," one said, "but I think cars like these will have to catch on after a while."

Citing dwindling petroleum resources that could mean the end of today's automobiles, another said, "The potential is there. It's sort of like the first airplane. This is only the beginning."

The Morning Sun

Pittsburg, Kansas, Monday, October 15, 1979—14 Pages, 2 Sections



Air power

"Guess I'm going to be an air advocate," said Terry Miller on the occasion of setting a new air-car speed record of 28 or 29 miles per hour (the measurement was made by a friend following in a standard automobile) Sunday in Crestline. He is pictured above on one of his runs down the highway through Crestline, and, left, triumphant after pulling a pickup-camper about 200 feet up a slight incline, a feat he didn't think Air Car I could perform. "I'm dedicating my next few years to promoting the use of air — from windmills to cars," said Miller. (Sunphotos by Dan Dyer)

Air Car Speed Tested

The Joplin Globe, Monday, Oct. 15, 1979—3A

By BECKY SPRACKLEN
Globe Staff Writer

CRESTLINE, Kan. — Contrary to popular belief, the invisible stuff we breathe every day is capable of propelling a car at the rate of 26 to 28 miles per hour.

Air, the only substance most people consider to be free these days, has been harnessed and controlled by Terry Miller, Crestline, to fuel his Air Car One.

At 2 p.m. Sunday, Miller took his invention for a speed-test drive, and impressed the crowd which had gathered outside his shop in Crestline by zipping along at a jaunty 26 mph, according to Fred Rosenberry, Joplin, who drove his truck alongside Miller's car and clocked its speed.

Oddly enough, Miller reported that "unofficially, Air Car One went 32 miles per hour the first time we timed it. That was probably because we recorded it when the car was much lighter, and had a lighter driver.

"I've souped up this model, added a cylinder and put the throttle in reach of the driver. It weighs more than the early stock model."

Miller's first tests in Air Car One, July 19 and Aug. 19, were not made to establish speed records. They basically were aimed at determining whether or not the car was a practical invention. Now that the car has become better publicized, the inventor decided that the time had come to try out its acceleration rate and speed potential.

With an ambulance from Derfelt's Reliable Ambulance in Galena cruising along behind him, Miller chugged up Highway 26, swung Air Car One into a U-turn, and opened up the air valves to full power. Within minutes, the test run was finished, and Miller stopped in front of his observers to let his wife climb into the passenger seat and take a "victory spin" with him.

Once he had finished a run with the original axle, Miller wanted to put his "high-speed axle" to the test. So he and Mike Samuels, assistant test-driver, and Dave Markley, mechanic and assistant builder of the car, changed the axles. Then Miller hesitated.

"I've never had a failure in the pneumatic system," he glowed, "but this axle could break any ole' time."

Rather than setting a second speed record, he decided to attempt a different feat with Air Car One — chaining a vehicle to the rear bumper and pulling it, uphill.

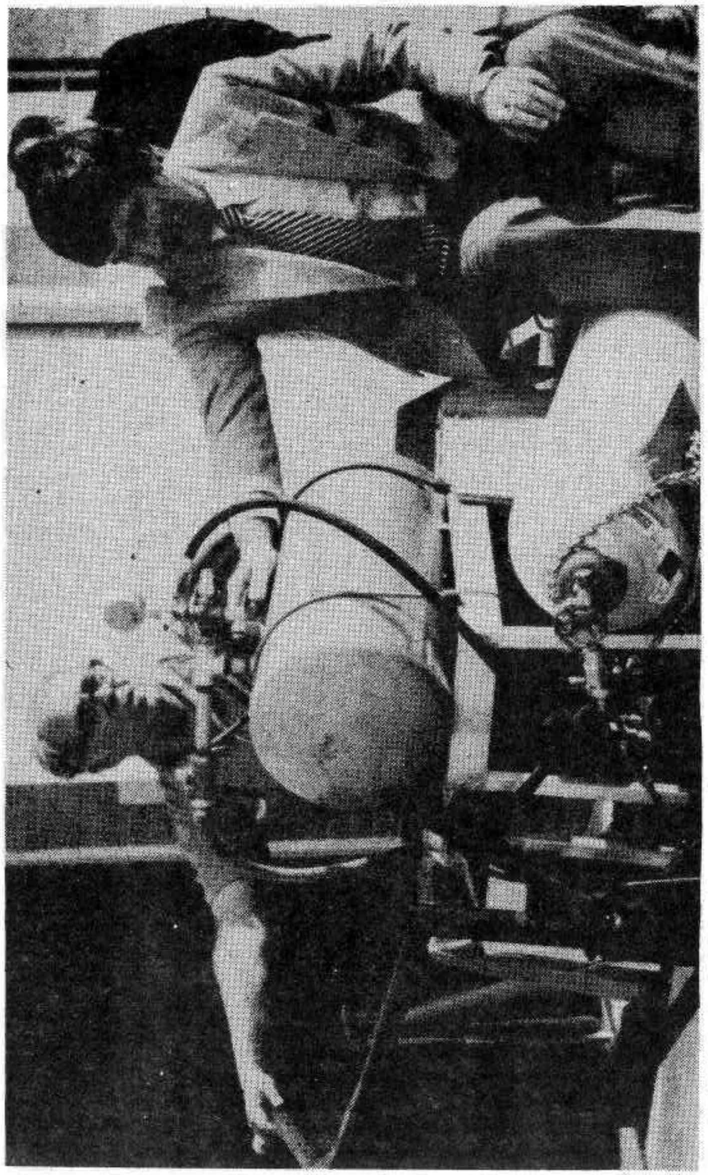
The car successfully towed a pickup truck on an incline, after a little push from bystanders to get it started, and Miller stood on the seat while the car was in motion, shouting "we did it! This car has sheer brute power."

What is next on Miller's schedule? Well, he and his wife, Sharon, have been invited to Dodge City, Kan., for "some sort of energy conservation symposium there. They have invited all people who have energy-saving ideas."

Air Car One certainly is an energy miser. Indianapolis 500 material it may not be, but Miller says he plans to keep on working on his idea. Air Car Two of the future may even hit a top speed of 55, he said.

But that's the legal limit anyway.

THE HIGH PLAINS JOURNAL
The Farmer's Paper
ALL EDITIONS—Oct. 29, 1979



TAKING A RIDE—Kansas Governor John Carlin is getting ready for a trip around the parking lot in a compressed air-powered vehicle designed and built by Terry Miller of Crestline, Kans. (left). Governor Carlin was one of thousands of visitors to the High Plains Energy Forum to get first-hand information on various alternate energy sources.

MY EXPERIENCE IN GETTING THE FACTS ON THE ACTUAL COST OF COMPRESSED AIR

by Terry Miller

When purchased from welding supplies dealers bottled compressed air can cost as little as $10.50 to as much as $26.00 for a "T" size cylinder containing 330 cubic feet of compressed air. The more expensive air is usually certified breathing air. This has been enough to turn most experimentors or inventors away from any serious consideration of using compressed air for experiments in motive power. Old stories that it is illegal for an individual to own or refill cylinders doesn't help much either. Air cost at retail did not detour me, because, I reasoned that if car owners owned their own compressor or a share in an air station compressor, cost would be less. I had to know how much less, which led me to a search lasting from May 1979 to September 1979. Digging for facts like an investigative reporter I uncovered an "Air Story" that is interesting and informative. I found a growing but comparitively limited demand for higher pressure compressed air. By this I mean pressures above shop use pressure or pressure above 200 P.S.I. Another gas "Nitrogen" is commercially available cheaper than compressed air, from welding supply dealers. The retail price of cylinders of Nitrogen gas often runs from one to two dollars less than compressed air. Cost to produce and retail cost are two different things. Nitrogen is in the air we breathe and forms about 80% and Oxygen the other 20%. Compressed air contains the same amounts 80% Nitrogen and 20% Oxygen. The production cost of pure Nitrogen and pure oxygen is reasonably fixed as oxygen and Nitrogen production involves an in plant operation using much larger amounts of electricity than required to merely compress air. To produce Nitrogen and Oxygen you must produce refrigeration, run expansion turbines, compressors, valves, piston pumps and electrical instruments. Producing oxygen and nitrogen by separating these gases is not a simple one step operation. The large plant complex of a liquid gas plant requires human labor for operating and maintenance. Yet, in spite of this difference in production cost, air is sold at retail for higher prices than compressed nitrogen. Why? Some reasons for the high price of air are simple and easy to explain away, some are not. Distribution costs including trucking, handling, making out invoices, bookkeeping, normal retail mark-up, etc., are all easy to explain as justification for high air cost per cylinder. Not so easy to figure out is this; Some compressed air sold in Joplin, Mo. and Pittsburg, Ks. costs $15.00 less per cylinder than the same air costs in Tulsa, Ok. And! this air available in Joplin and Pittsburg is compressed and the cylinders filled in Tulsa. Why? The answers are rough, but, here are the facts. The retail price charged for compressed air is a rip-off, but, the sound economic facts of our free enterprise system make it so. Usually just fire departments and scuba divers get bent out of shape over the cost of compressed air at retail. But, enterprizing air compressor and gas cylinder distributors are springing up to fill their demands for cheaper air. Changing events have made keeping many trade secrets impossible. Gas producers' old trade secrets are being stolen, bought, shared, and learned because of a new and increasing demand for higher pressure compressed air. Air and also high pressure natural gas for automobile and truck fuel.

Producers of nitrogen and oxygen would be crazy to sell compressed air at a price reflective of actual production cost or a much much lower retail price than nitrogen. Other than for breathing purposes compressed air has a substitute. You have probably guessed it by now. That's right! Nitrogen. Nitrogen can be used for almost any small job for which an individual needs higher pressure compressed air, except for breathing or a laboratory use in which an inert gas like nitrogen could not be used. Nitrogen is used in industry. One use is as a shielding gas to keep oxygen and impurities away from electronics components during their manufacture.

There is no such thing as a little nitrogen and this is the bottom line answer for compressed air prices being held sky high. A gas producer cannot just pick or filter nitrogen alone, out of the air in a (gaseous) state and compress it into cylinders to sell. Oxygen alone, cannot just be picked or filtered out of the air in a (gaseous) state and be compressed into cylinders. Gas producers supply demands for pure oxygen and nitrogen in both gaseous and liquid forms. The facilities to separate these two gases requires an industrial complex called a "Liquid Gas Plant". Whereas filling a gas cylinder with compressed air requires only an air compressor and very little electricity, because no gases have to be separated. A low pressure liquid gas plant makes and separates liquid gas from air like this; Air is compressed in it's path through the complex. A plant pressure of 70 to 80 P.S.I. is maintained. Air is cooled to remove water in a reversing heat exchanger path. Carbon dioxide is removed and vented to the atmosphere. An expansion turbine is used to expend air suddenly, but, temporarily to 5 P.S.I. which produces refrigeration. At - 312°F Nitrogen in the air turns to liquid. At - 297°F Oxygen turns to liquid. The liquid then flows into a column designed to separate the two liquids. "Tray Technology" is a term used to describe this portion of the process, in which multiple trays simular to a cheese grater suspended within the column aid the separation of liquid nitrogen and oxygen which occurs due to their different weight or (specific gravities). Pure nitrogen in liquid form is drawn off. Enriched liquid oxygen is drawn off into another column for further purification till pure. These liquid gases when viewed in an insulated clear glass beaker are a sight not soon forgotten. Liquid oxygen is a pale blue or sky blue which is what causes our sky to be blue in color. It's like seeing the sky in a bottle. The look of liquid nitrogen could be described as a small glass of water with a few drops of milk blended in. Liquid nitrogen also has a fog on its surface like the fog everyone often sees over water.

Liquid gas takes up much less space and is often transported in liquid form. To fill gas cylinders a small dia. long stroke piston pump is used to pump liquid gas into a manifold. In the manifold it warms enough to change back into a gaseous state and from this manifold it flows into the gas storage cylinders in a compressed state. If you look around your city near welding supplies distributors you can probably find rather large vertical storage tanks containing liquid oxygen or nitrogen. At the base near these tanks are piston pumps to pump the liquid gases into the filling manifolds. The pressure of (bypass) valve setting on these pumps controls the gas pressure the cylinders connected to the filling manifold are filled to. Air has to be liquified to get pure oxygen or nitrogen. Air is 80% nitrogen 20% oxygen. Most all gas producers, produce more nitrogen than they call sell. They have to produce nitrogen to get oxygen. It costs to produce nitrogen. Nitrogen is vented into the atmosphere everyday. The cost involved is still there but if a demand is not there it is let back to nature even though electrical energy was used to produce it. Most gas producers have men on their payroll whose only job is to sell nitrogen and to find new uses for it. "The fact that compressed air is dirt cheap" has been the best kept secret in the gas industry. Now this is the botton line reason why you cannot buy compressed air from welding supplies distributors at a cheap price. You can buy all the nitrogen you want. But, all gases sold have to bring in enough money to pay for any gases which have to be produced which are not in demand. It requires approximately ten killowatts of electricity to produce and compress 300 cubic feet of nitrogen. It requires a fraction more than two killowatts to compress 300 cubic feet of air. Oxygen and nitrogen production requires an industrial multi-step complex plus several people. Compressed air requires a compressor.

Telephone conversations with executives of gas producing corporations helped. I was told that if demand for compressed air was high, cost would come down. Air sales are only a very small fraction of total gas sales. I was told, if owners of air powered cars left empty tanks and picked up full tanks with no delivery labor involved air could possibly be sold for $2.00 per "T" size cylinder. But, only if demand were high. The reasons for their high costs for air were given to me, as distribution costs, low volume and the nitrogen surplus causing no real desire to push air, which is understandable.

Future air car owners don't want to juggle air cylinders, but, rather hook up a hose and air her up and be on their way. I only proposed a method whereby cylinders would be exchanged in order to get views and opionions on a specific way to set up an air station. Also, to obtain an estimated cost per cylinder figure from the gas industry people.

Scuba diver supplies stores in Joplin, Mo. and Pittsburg, Ks. were visited and an answer to air station function was found. "The Cascade System" used for filling scuba diver tanks. With a storage tank system the need to exchange air cylinders is gone. Compressed air cylinders permanently installed in the car and filled by an air station "Airup" hose in a few minutes was the answer. Both cascade systems employed a 5 H.P. - 4 stage air compressor for filling the cascade system tanks. Learning the natural gas supplier for Joplin, Mo. The Joplin Gas Company had a larger compressor led me to seek their help. I learned the same system needed for air cars is already used nation wide on our highways. Oh! lucky day when the management there let me check out their fill system for myself. Their compressor was on a separate meter. Words cannot describe how thrilled I was with the results of my own readings of power consumption during the filling of gas cylinders. Also, in talks with the men at Joplin Gas Co. their figures agreed with mine. Being raised in Missouri I have to see it to believe it. Finding it hard to believe my own figures, because of all the B.S. I had heard about high pressure gases, I proceeded to write all the figures and data from the electric meter to check with the Electric Company in Joplin. Maybe the meter was a (reading times ten type) where the actual reading is multiplied by 10. I checked with the Empire District Electric Company of Joplin, Mo. I read every number and symbol to their meter expert and got an explanation of each. Still not satisfied another visit to the Gas Company for a look at some of the electric power consumption records and electric bills for the compressor, plus a check of the hour meter from date of new to that days date and then double checked, and I was a believer. Then it hit me for real. I had an air powered car that was cheap to run. Subsequent checks on air compressor maintenance costs let me know that for overall cost utilizing quick fill air stations an air powered car had gasoline beat, and that was when gasoline was only 90 cents per gallon.

In this search for the story on compressed air I heard a lot of pretty far out stories. I listened to the stories, but, obtained my own documented cost figures. One, of a man in Springfield, Mo. who in 1932 was running his car on air. He vanished, car, furniture, belongings and all. This story came from a reputable welding distributor who related this story as from his own personal knowledge. I do not believe stories that a certain carburetor design was bought and kept secret or that auto manufacturers would do this or could if they wanted to. Yet sometimes we all wonder, I do not fear for my safety or the safety of my family. Mulitple copies of the invention disclosure of my air car are in good hands. In most all foreign countires and every state in the U.S. and Province in Canada.

A NEW DIRECTION FOR INVENTORS

I'm convinced that I am the first person to actually document how far a wheeled vehicle could go on a certain amount of air. This was done before I documented the actual cost of compressing air. Till now the main draw back to air powered cars has been no range. The simple fact that an air powered car could not carry enough air reserves to travel more than a few blocks or very few miles has led inventors off in the wrong direction. This wrong direction has been toward a way to replenish or re-fill the cars air tanks by some means carried within the car. Patents have been granted for some of the most complex machines imaginable. Most of these inventions were new art, new idea type inventions but, an invention has to work and be practical if it is to find a place in the market place. The fact that most all patents on air powered cars include a new or novel way to replinish the air supply tanks while driving is enough proof of the fact that inventors acknowledged that they could not go any distance unless air supplies were replenished by an on board means on a continuous basis.

My method of using the air several times in stages before exhausting is simple, but, new! Using air more than once gives more usable power per cubic foot of air and gives more speed and range than possible with any other method of air use to date.

Another reason inventors have gone the wrong direction is because gasoline has been cheap. For this reason they knew an air powered car would have to operate for free so to speak. How do you beat cheap gasoline. Easy they thought. Just use air to power the car and re-pump the air as you go. I am the first to admitt that air powered cars have been considered foolish. But inventors have concentrated on replinishment instead of effeciency. From my study it is apparent that no real serious attempt at effeciency was considered because, to compete with gasoline a machine bordering on a perpetual motion machine would be necessary. Inventors were after something for nothing because with cheap gasoline there was no other direction to go. I am amazied at the number of patents granted for self-replenishing air powered cars. Some air replenishment patents are pretty far out, but, others look as though they hold out a promise of partial air replinishment although I personally doubt this. It requires energy to compress air and trying to use the cars motive power to compress air is self defeating.

I would ask future inventors of air powered cars to turn away from the concept of an onboard method of air replenishment and concentrate on possible improvements in my pneumatic engine or a new invention directed at even better effeciency. If one is driven to explore air replenishment a check of all the old patents could save a lot of waisted time and possibly guide one to a new concept as yet not thought of. I get several letters a week saying, "I have an idea". "If you could put a compressor in the car and drive it with the axle or a electric motor compressor powered by a generator you could make your car self sustaining."

	Cyl. 1 Pf. 3	Cyl. 2 Pf. 5	Cyl. 3 Pf. 8.3	Cyl. 4 Pf. 12.5
P.S.I.	100	45	20	4
P.S.I.	150	84	34	8
P.S.I.	200	104	46	17
P.S.I.	250	180	80	40
P.S.I.	300	190	100	51
P.S.I.	350	220	115	53
P.S.I.	400	232	126	64

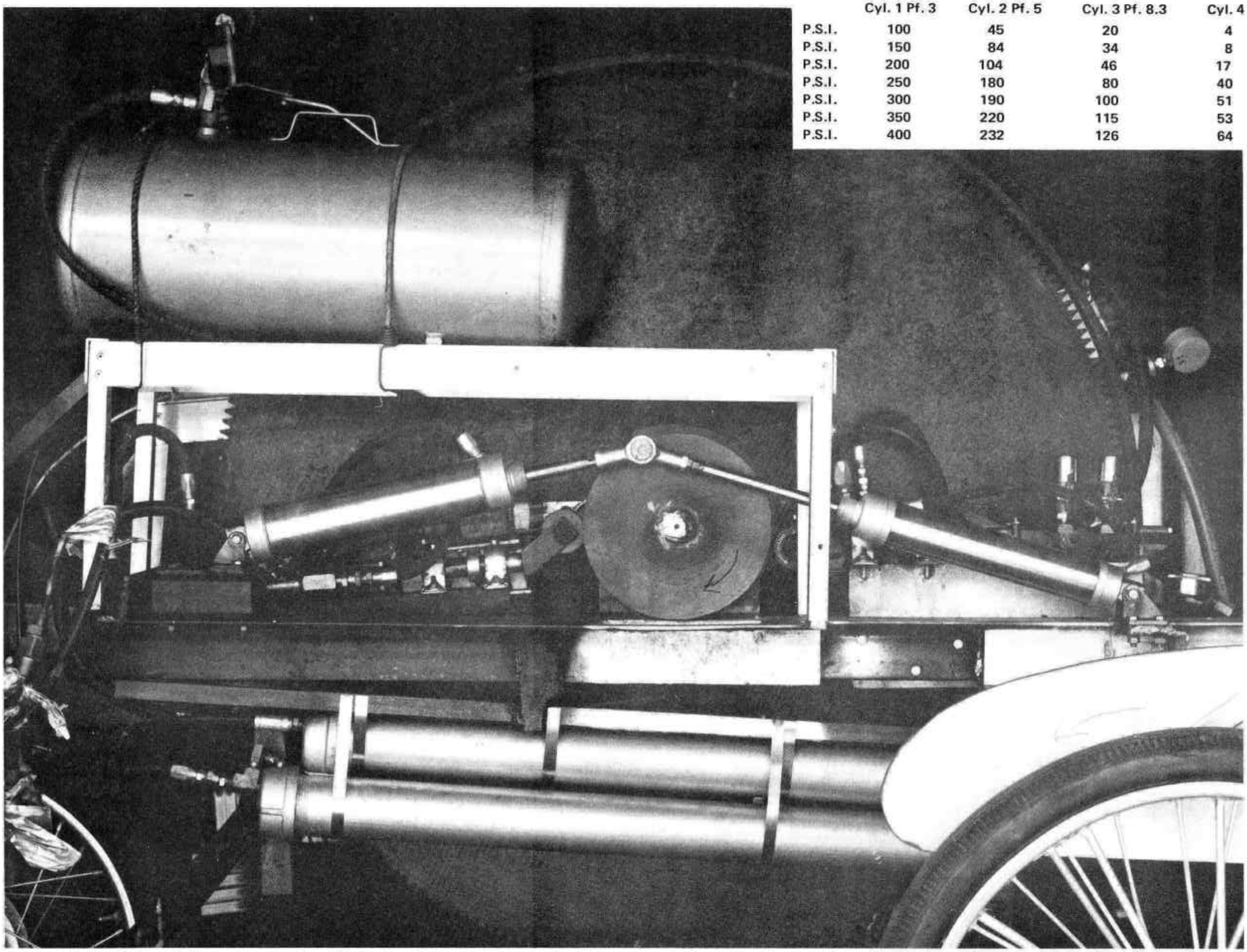


Photo shows left side of air car 1. Two more actuating cylinders have been added to car to further prove out my invention. By compairing with photos on other pages one can determine new items added to car. Actuating cylinder on right is No. 1 now. It is 2" bore and first to use air. It has a power factor of 3. Actuating cylinder on left is now No. 2 and has a power factor of 5. No. 2 uses the exhaust air pressure from No. 1. Power factor is determined by cylinder bore size. Cylinder force is determined by multiplying power factor by air pressure. Adding more actuating cylinders improves the mechanical effeciency of the engine. Also it increases power in proportional steps. The power factor ratio of cylinder No. 1 to cylinder No. 2 is 3 to 5. Air pressure drop No. 1 to No. 2 is 50%. A proven engine design formula is; Pf. 3 to Pf.5 = 50% P.D. In designing a pnuematic engine each cylinder is increased in bore (size) thus increasing it's power factor (Pf.). This enables each actuating cylinder to deliver the same force as the cylinder before it in air use. The cylinder arrangement shown is not the best as far as mechanical effeciency is concerned. Actuating cylinders were added where possible to prove out my invention by using air 4 times before exhausting it to the atmosphere. A listing of the operating air pressures of all four actuating cylinders along with power factors are shown. These figures were compiled while driving the car in Dec. 1979.

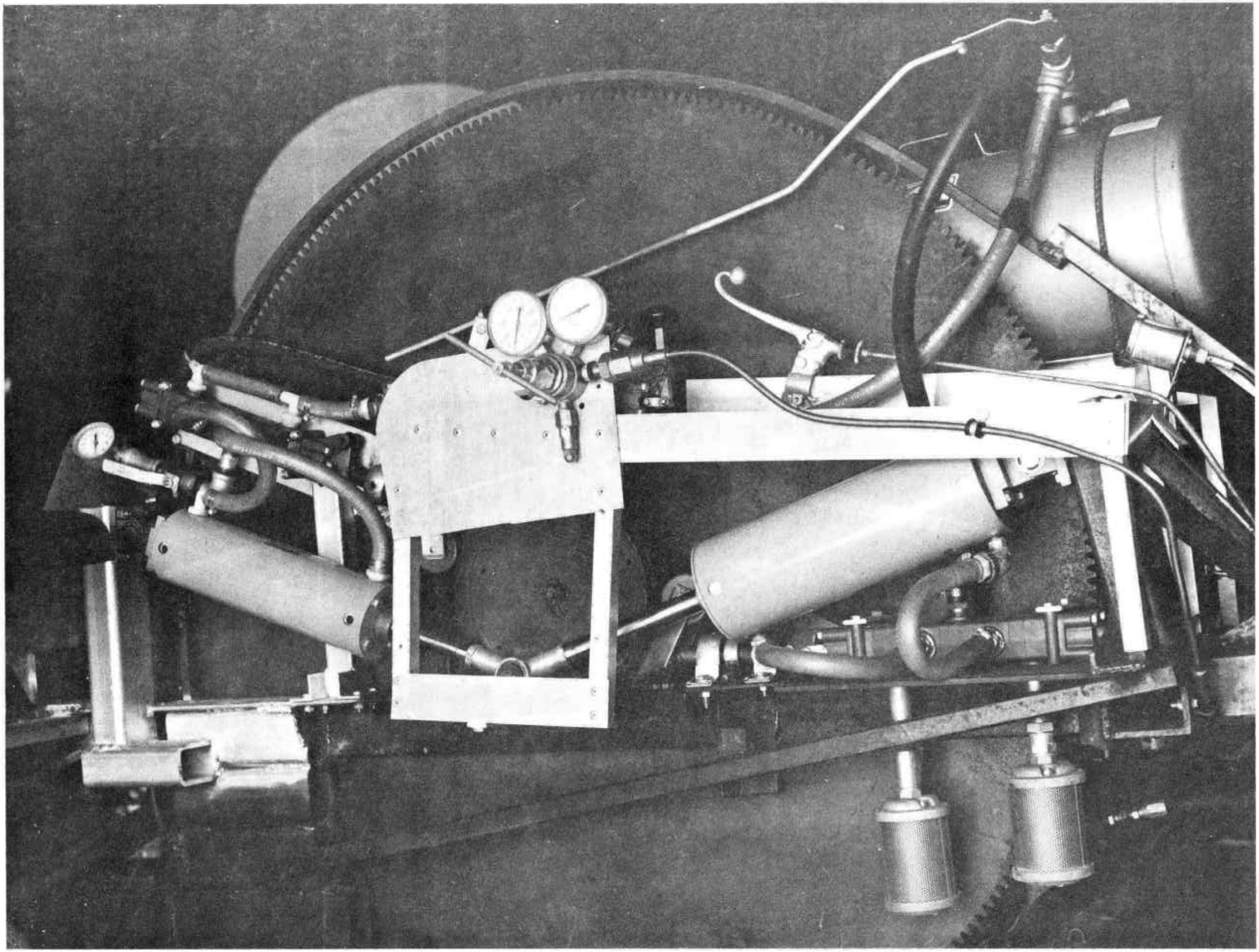
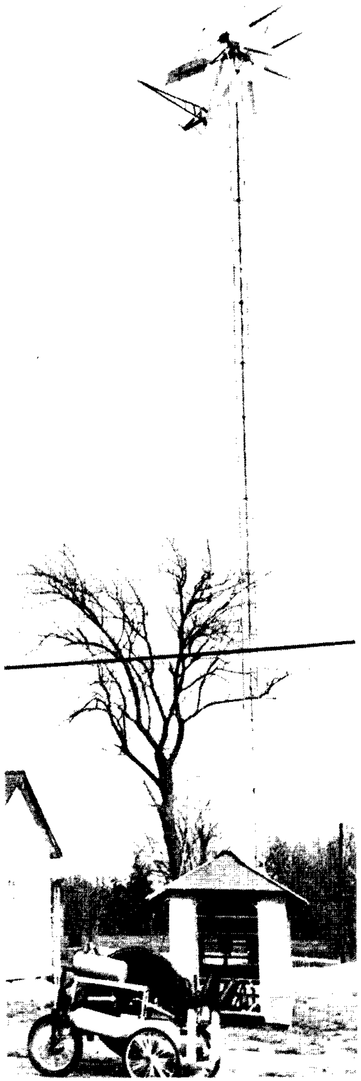


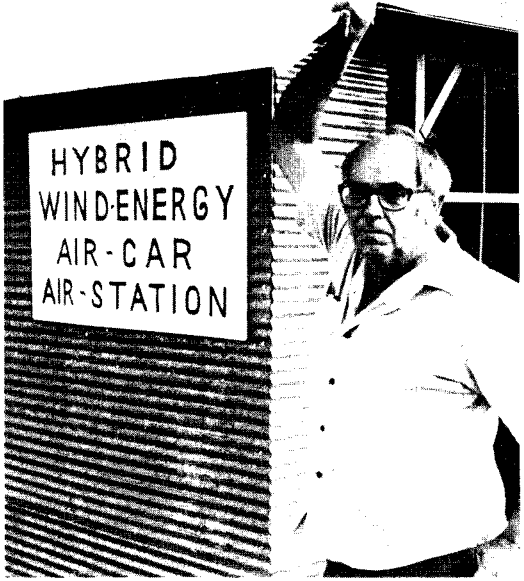
Photo shows R.H. side of air car 1. The actuating cylinder added toward making four actuating cylinder car is on the left. It is a 3¼" bore cylinder with a power factor (Pf.) of 8.3. This cylinder (left) became actuating cylinder No. 3 and gets its operating air from the exhaust air of cyl. No. 2. Actuating cyl. No. 4 is the same 4" bore cylinder shown in other pictures in this booklet being used as cyl. No. 2 when the car had only two actuating cylinders. The air tank shown upper right is a pressure tank (19). It supplies air to No. 4 cylinder. Adding two actuating cylinders required adding two more tank (19)'s to the car. These tank (19)'s were constructed of 2½" pipe. They show in other picture of L.H. side of car. The pivit for No. 3 actuating cylinder was positioned high so these two cylinders would not be directly opposed to each other. No. 3 actuating cylinder air system does not have a vent valve to the atmosphere. In other words no pig valve is installed to operate, because of lack of space for it and a timing cam to operate it. Cylinder No. 3 has its power cut considerably due to back pressure from the tank (19) supplying air to No. 4 cylinder. This car is crude in construction,but, is in fact my patent vehicle. Patent application drawings of air car 1 with two actuating cylinders are on file with my patent application in Washington D.C. "Patent Pending". General design improvements are most obvious to those experienced in air use and vehicle design. Design improvements can only improve the performance of the original vehicle.

THE FIRST PUBLIC DEMONSTRATION OF A WIND ENERGY MOTOR VEHICLE TRANSPORTATION SYSTEM NOVEMBER 10, 1980 IN CRESTLINE, KANSAS.

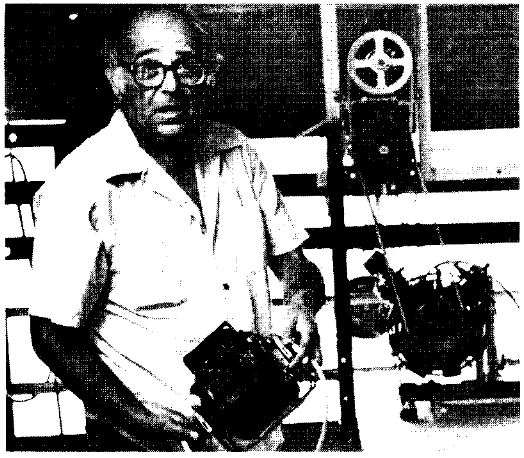
Two air powered cars took the first ever passengers for rides using a wind energy motor vehicle transportation system. Terry Miller's air powered car and another called, Air Car 1-A built by five physics students from Buffalo High School at Buffalo, Oklahoma. Gwen Cook the students physics teacher was the first passenger on the new wind energy system. Both air cars received "air ups" of wind energy (pressurized air) motor fuel during this history making demonstration. A air up hose was used to transfer pressurized air from Miller's air station storage tanks to the cars air tanks. During the demonstration the students air car was driven by Ronnie Catlin, taking several spectators for rides as the students teacher Gwen Cook looked on with pride.



Air like you and I breathe transformed into a compressed motor fuel utilizing wind energy. God's wind and God's free air can be a weapon used by the energy poor against exploitation by the energy rich Arabs.



Terry Miller, 1918 Bank Bldg., Crestline, Kansas 66728 (316)389-2299



Educational TV video tapes explaining vehicle or air station theory and operation are available for loan or purchase.

NOTE! This is a totally! NEW! Invention! the likes of which has never been needed before. It is inevitable that some misconceptions will occur. This system consists of a windmill, direct driving a - air compressor. This system is not for generating electricity as it's primary function. Some useable electricity is generated as a by-product of the speed governing A-C motor generator portion of the total hybrid system. This wind energy air station is a case of one invention (an air powered car) causing a need (for a cheap energy efficient fuel) and the resultant search leading to another invention (a hybrid wind energy air station).

Wind Energy Is 100% Energy Efficient

My thanks to Al Story of the Columbus Daily Advocate for photographs and a very accurate description of my Hybrid Wind Energy Air-Car Air-Station.

Gasoline-powered cars stop at gas stations, so naturally air-powered cars need 'air-stations'. Better yet, Terry Miller says that anyone driving through Crestline in an air-powered car can stop at his air station for a free fill-up.

The Crestline man, inventor of his own air car who offered the plans for the vehicle free of charge to anyone, has now constructed an air station which he believes will be the launching point toward increased demand for his 100 percent energy efficient transportation system.

Very simply, it works like this:

— Wind turns the blades of a windmill and the motion is transferred through pulleys and gears which increase the revolutions per minute.

— The rpm's thus generated are used to operate an air compressor.

— Compressed air is stored in tanks for whenever the air car needs a fill-up.

— Thus no energy cost is involved in the transportation system. The only energy imput is "free as the wind".

An extra added benefit of Miller's air station, and the reason he calls it a "hybrid system", is that it can also generate electricity. An ordinary electric motor is attached by pulley and belt to the shaft turning the air compressor.

When winds provide the number of rpm's at which the air compressor is supposed to operate, electricity is neither used or generated. When winds increase and the rpm's begin to "overspeed" the compressor, the higher motion transferred to the electric motor causes it to begin generating electricity which Miller says he can then transfer to his home adjacent to the air station.

When winds are below the level needed to compress air, the electric motor can be used in the normal manner to help pull the compressor. In this hybrid system, Miller says, he is buying electricity from his house when winds are low and selling it back to the house when winds are high.

The electric motor also operates as a governor on the air compressor, slowing it down when it reaches overspeed.

Miller pointed out it is difficult to store electricity, but air is easily, and in his system freely, stored. Thus energy is stored until needed.

AIR POWERED CARS

For Additional
Information
Call or Write

Terry Miller
Air Powered Cars
P.O. Box 80 316-389-2299
Crestline, Kansas 66728

My air car invention has six complete sets of documented performance figures, obtained in six different cities by six different groups of ultra-reliable people. These figures were duly published in leading newspapers as documented facts on performance. Also, this was done in a period of only seven days and with no mechanical malfunction of my machine. Different newspaper people learned how to drive my car and were turned loose to report the facts and figures.

No other air powered car invention anywhere in the world has been able to provide its inventor with any such documentation. I can assure you and would gladly bet my life on this, that no other air powered vehicle can ever achieve such figures unless it uses my new method of sequential re-use of pressurized air or an improvement on it. The name, reputation and staff of six reputable newspapers stand behind this documentation.

XEROX COPIES FOR FRIENDS

The following newspapers can attest to the documentation

The Columbus Daily Advocate, Columbus, Kansas 66725, Phone 316-429-2773, published June 19, 1980;

The Baxter Springs Citizen, Baxter Springs, Kansas 66713, Phone 316-856-2115, published June 23, 1980;

Miami News-Record, Miami, Oklahoma 74354, Phone 918-542-5533, published June 29, 1980;

The Carthage Press, Carthage, Missouri 64836, Phone 417-358-2191, published June 26, 1980;

The Chanute Tribune, Chanute, Kansas 66720, Phone 316-431-4100, published June 27, 1980;

The Coffeyville Journal, Coffeyville, Kansas 67337, Phone 316-251-3300, published June 27, 1980.

No other air powered vehicle has ever been able to be demonstrated from one coast to the other in the following cities:

Crestline, Kansas
Pittsburg, Kansas
Joplin, Missouri
Columbus, Kansas
Baxter Springs, Kansas
Miami, Oklahoma
Carthage, Missouri
Chanute, Kansas
Coffeyville, Kansas
Springfield, Missouri
St. Louis, Missouri
Indianapolis, Indiana
Columbus, Ohio
Harrisburg, Pennsylvania
Pittsburgh, Pennsylvania
New York City, New York
Baltimore, Maryland
Washington, D. C.
Dodge City, Kansas
Amarillo, Texas
Wichita, Kansas
Kansas City, Missouri
Tulsa, Oklahoma
Oklahoma City, Oklahoma
Dallas, Texas
Fort Worth, Texas
Houston, Texas
San Antonio, Texas
Tuscon, Arizona
Phoenix, Arizona
San Diego, California
San Francisco, California
Sacramento, California
Fresno, California
Bakersfield, California
Los Angeles, California
Flagstaff, Arizona
Albuquerque, New Mexico

There is no other such vehicle in the world and never has been before. Stories, yes, but none that could do it. I offer the following conservative information.

I have all the answers in regards to my invention to produce a town transportation car to carry two passengers; to have a range of 45 miles; to be able to be refueled with air in four minutes; to be of less total operation cost per mile than a battery powered car; to be as energy efficient as a battery car; to be able to be driven all day where a battery car can not; to speed up mid-range rather than slow down like a battery car; to absolutely not polute the air; to actually clean the air as it is used in the air station and car system; to derive considerably more miles per barrel of crude than a gasoline powered car of comparable weight; to be able to be produced promptly with no secret or unanswered technical questions yet to be solved prior to production.

Terry Miller

Take one!

★FREE★

UNITED STATES GOVERNMENT

is quietly furnishing complete building instructions, including engineering drawings, (many pages) on: Where to buy parts: How to assemble: And road test your own

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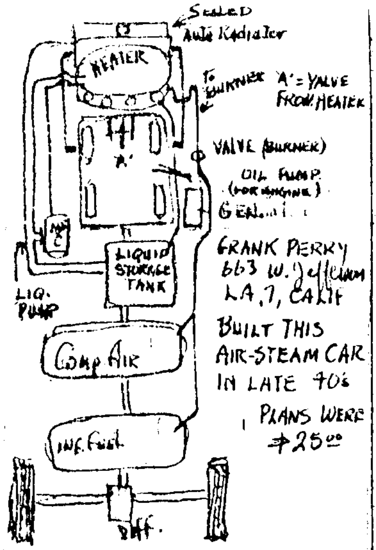
AIR POWERED CAR

You need only write to Commissioner of Patents, Washington DC, 20005. Ask for the building instructions for the only street legal, United States patented, air powered vehicle in the United States. Document number #4,370,857.

PERRY MOBILE



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LIQ St. Tank COLLECTS LIQ AS IT Condenses IN RADIATOR
NO FURTHER DATA FRY 65

Incredible car runs great on cheap compressed air

An amazing new car breezes along powered only by air. And inventor Terry Miller says his incredible machine is the ultimate answer to the energy crisis and pollution.

By STEVE PETRONE

The 47-year-old engineer from Crestline, Kans., built his air car to prove that an old idea's time has finally come.

"This isn't a new idea. The first designs for air-powered cars go back as early as 1894.

"But for the past 90 years development of the air car has not been feasible. Now, with gasoline prices as high as they are, it makes terrific sense," says Terry.

Terry's car runs on a compressed air system which he invented. Two compressed air cylinders send blasts of air to the rotary-shaped, eight-cylinder engine.

By the time the air reaches the exhaust system it's actually cleaner than when it left the cylinder.

The inventor says top cruising speed for the car is 45 miles an hour. And Terry is in the process of developing a system which will give the car a range of 45 miles. While Terry is not hoping to put any Detroit auto makers out of business, he thinks he's got the beginnings of an ideal in-town runabout.

"We've got electric cars beat by a long shot. You can't drive them all day — their batteries get weak and you have to stop and recharge them.

"But with our air car you can just pull up to a pump, fill the tanks with compressed air, and you're off again. And it's cheaper to run than an electric car," Terry said.

The only thing Terry's car lacks right now is glamour.

But he's quick to explain that he didn't build it to be beautiful — he built it to be practical.

He's spent the better part of the last two years developing and refining the drive system. He says a better-looking body will be constructed around his engine eventually. But for now, he's satisfied to look like a traveling garage sale as he merrily tools down the road in his air car.

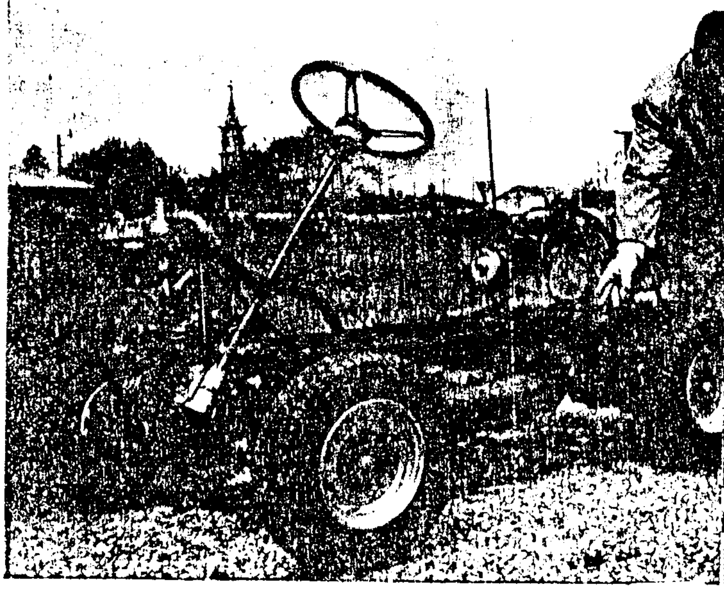
Aside from the air car's appearance, Terry's biggest stumbling block has been funds. He's applied for a $2 million federal government grant to continue development. And he just completed a cross-country tour to show his car to the public in an effort to gain support and publicity.

"It's so close right now, and the need is so great, that I'd hate to have to stop development because of money. But I've devoted two years to this car now, and I may have to go back to work soon."

WEEKLY WORLD NEWS, October [illegible], 19[illegible]

AIR MOTORS FROM:
SOUTHWESTERN CONTROLS
5633 S.W. FREEWAY
HOUSTON, TX 77057
(GAST mod 8AM FRV 30A is $175.00)
ASK FOR HARRY HAMILTON —

HERE IS VITTORIO SORGATO'S AMAZING LITTLE COMPRESSED AIR AUTO NEAR MILAN ITALY (73)

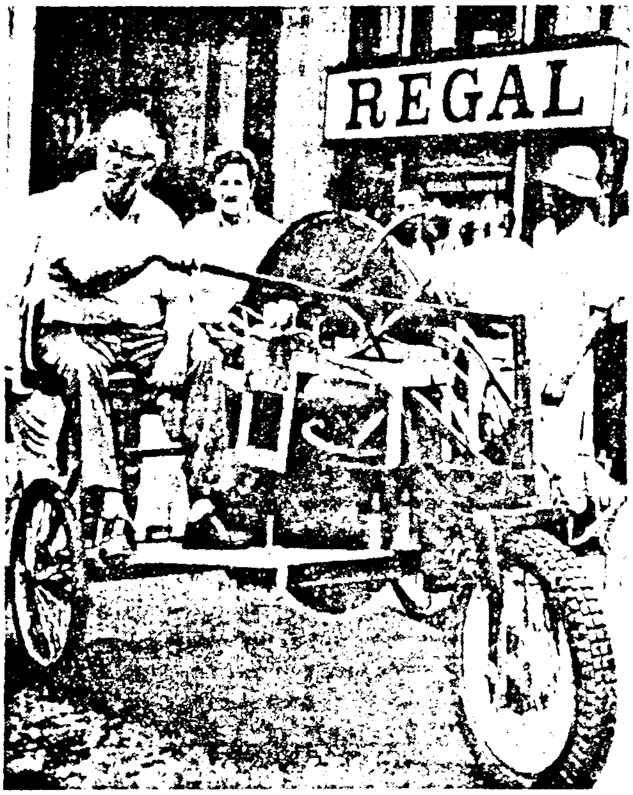


Terry Miller, left, takes a passenger along for a demonstration ride in his incredible air-powered automobile.

If a man
dwells on the past
he robs the present —
If a man
ignores the past
he may rob the future.
CHINESE KUNG FU

COMPRESSED AIR CAR

Photocopying technology has improved so much in recent years that now i can reproduce this photo that i cd only describe in words in 1980. This is the air car i mentioned in LF9p8, being shown off in Times Square. The letter below refers to this car. My comments follow the letter from Luther.



RIDING ON AIR — Terry Miller of Crestline, Kansas, talks to people in New York's Times Square as they gather around to look at his compressed air car. Miller says his two-passenger car costs about two cents per mile to run, cruises at 29 miles per hour and has a range of about 10 miles. He said he built the car for about $850.

LETTER FROM LUTHER (Dec 86)

Dear Jim,

Thanks for the back issues on compressed air and air cars.

Terry Miller, the air car inventor mentioned in LF#9, is a personal contact. I've driven his car extensively & can provide 50 pages of technical data, building plans & documentation on it, or you can get a better copy from him (TM, Box 80, Crestline, Kansas, 66728). His car can go about 45 miles between fillups with 4 "T" sized tanks at 2250 psi, or 1320 cubic feet of free air.

I've researched air cars for seven years, and have collected articles and patents on dozens of modern air car inventors. For real technical how-to, the best source is old compressed air engineering books, and journals such as "Street Railway Journal" and "Engineering News". For info on building an air car from off-the-shelf parts, Terry Miller's book is useful--his car cost him $1500.

Compressed air locomotives were used extensively in mines and metro transit from about 1880-1930, because of their highly advantageous characteristics such as high torque at low speed, quiet, non-polluting, simplicity & dependability. Till the 1920's they always used an on-board reheater--usually a pressurised tank of hot water through which the fuel air bubbled on its way to the engine, or steam injection later on. Then in the 1920's the "atmospheric interheater" replaced the fuel-consuming reheater. I call it an ambient heater. In a two-stage engine (such as Terry Miller's) the air exhausted from cylinder one is 75-80 degrees below zero F., and is still under pressure. It goes into the ambient heater, a passive heat exchanger with no moving parts, and is raised back up to almost atmospheric temperature again, then used to push a second piston. Driving range was thus increased 30% with no fuel cost. After this device was in common use, the textbooks were wiped clean of all references to efficient air engines, and such engines are no longer available on the market. Engineers are in their second or third generation of trained ignorance on the efficient use of compressed air in engines.

Most modern inventors, unlike the old-time pneumatic locomotive engineers, are working on designs for self-fuelling air cars that don't have to stop to refuel. Not perpetual motion machines, these cars probably take advantage of ambient heat coupled with the extreme cold of expanding compressed air, to draw enough heat out of the system's surroundings to make up for the system's internal losses. This works in any weather since absolute zero is -460 degrees F., and compressors are more efficient with colder intake air. Thus the baseline for such a system's operation is the temperature outside the car. Air engines, like steam, internal combustion, Stirling, etc., are heat engines--the air is just a medium for heat and pressure, their real fuel. The ambient heat intake expands the cold air, proportionately increasing its efficiency.

In order to attain maximum efficiency, the ambient air should be taken from around the finned heads of the compressor (of the air-cooled variety with the cooling fan removed.)

The ambient heater allows the use of 30% smaller equipment. Another way to decrease the size of the equipment is to use a closed cycle with the (still slightly pressurised) engine exhaust going straight back into the compressor. Because the air never expands back to its original atmospheric volume, a smaller compressor can be used.

Because of the ambient heat and the re-use of compression waste heat, this self-fuelling car makes more fuel than it needs, requires only a few tanks, and can be used in any size vehicle. This is a hybrid car using two fuel sources: internal heat/pressure and ambient heat. It is not a perpetual motion machine since one of its fuel sources comes from outside the thermodynamic system. Windmills, solar panels, etc. are also powered from outside themselves.

I sell a 377 page book called Air Car Access for those interested in more details. The documentation on the ambient interheater is in Robert Peele's "Compressed Air Plant" (5th ed., 1930) and his "Mining Engineers' Handbook" (2nd ed., 1927, vol. 2). The device was manufactured by H. K. Porter Co. of Pittsburgh--they're trying to locate more data on it.

Though my working model isn't yet finished, I wouldn't waste your time with idle speculation or perpetual motion cartoonery.

If you choose to print this in Living Free, please include the name and address below:

Luther, Box 1574, Grass Valley, CA 95945.

Comments: When compressed air (or any gas at room temperature) is released from pressure & expands, it gets very cold. (That's how a refrigerator works.) Then, if you bring warmer outside air (ambient air) into contact with this cold, expanded air in a heat exchanger, heat will flow from hot to cold. The cold air will get warmer, the (relatively) warmer air will get colder. This means energy is flowing into the system containing the cold, expanded air. If you take air from the atmosphere, extract heat from it in this way, & release it back into the atmosphere colder than you found it, you have extracted energy from it. So i have no doubt about Luther's claim of a 30% increase in efficiency using ambient air reheating. But i strongly doubt his claim concerning a car that "makes more fuel than it needs." (No such claim is made for Terry Miller's car pictured above.) The problem is quantitative: how much energy can you extract from ambient air in this way? Can you extract as much energy as the car consumes overcoming friction, accelerating, etc. plus what it loses in lost heat (energy) from hot tubing, brake pads, & other hot surfaces? I doubt that it can be done. Despite Luther's denial, i think what he suggests is an (impossible) perpetual motion machine. The way to prove my skepticism wrong (if it is wrong), is to build an actual working car. Don't tell me, show me - that's the best evidence.

Living Free, no. 40, Sept. '87.
Luther is AKA Scott Robertson.

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MEN IN BLACK VISIT AIR CAR PROJECT (1982)

Then along came Sadashiv wanting me to come on his radio show—he was a late night DJ on the local community radio station—to talk about air cars. I eventually condescended to grace the air waves with my presence once again, and my little air car cult was born. I was in my Terry Miller phase at that time. A friend of Sadashiv called the show from another town and invited me to his home, where I went and gave a whole lecture on Terry Miller's air car for several people.

Porsche Doer and Darshan were so hot on the air car project that I was forced to devise a plan of my own based on the best knowledge I could put together from my research, and as a trio ready to become a corporation, we hired a man out of the classified section to come "evaluate and help design and build" my invention.

This guy was spooky. In fact, that was his name: Mr. Spooky. He was a big tall husky guy with black hair and goatee, and dressed all in black: black shoes, black vest, black shirt, everything. I faultily remember him in a black cape lined with scarlet; this cannot be; it must be a fabrication of my fairly useless memory which is not to be trusted.

Mr. Spooky listened to me briefly explain my air car plans but stopped me way short of the best details, to explain to us with a sort of know-better laughing-down reproachfulness that, in spite of any truth there might be to any of the assertions that I was no doubt eager and ready to make about the superiority of my air car idea over the prevalent nonsense substituting for transportation, the government would never let us do it despite its obvious safety advantages, and not only that but the ammunition that the government propagandists would use to stop us would be *safety* concerns built on people's natural but unreasonable fear of pressurized tanks.

As Mr. Spooky confirmed, air tanks almost never break, explode, wear out, or fly through the air like unguided missiles, but a vision of fearsome consequences could easily be planted somewhere within the bureaucratic thought process to make it nearly impossible to put an actual air car on the market.

After expounding these points and others at some length, Mr. Spooky finally stopped shooting off his mouth and looked at Darshan, Porsche Doer, and myself, each in turn. To Darshan and Porsche Doer he said that he felt he had gotten through; to me he remarked that I showed no signs of letting go of the air car project. He thanked us for calling him, announced that he could not charge us for his services on this evening, nor would he be available to our project in the future, and he slipped into the night with his black briefcase.

Darshan and Porsche Doer eventually recovered and we continued to keep one eye open for an engineering consultant who was not afraid of doing a good thing in spite of status quo opinion based on ignorance and paranoia.

AIR CAR NUT MEETS AIR CAR INVENTOR (1984)

I went ahead and called air car inventor Terry Miller, after first interviewing the head of the Mechanical Engineering Department at a local technical institute, and being told that I was set upon a course of inquiry that would teach me more about mechanical engineering than I ever wanted to know. I told Terry Miller I was real interested in studying his air car up close. He said he would be happy to see me show up, so I drove on down to Crestline, Kansas where he lived at 1918 Bank Building.

His home turned out to be a real bank building built in 1918. There wasn't a need for addresses in Crestline, Kansas since there were only two buildings; Terry Miller was living in one and using the other to build his one-piece Styrofoam buildings in. He'd set his "Air Car One" aside after showing it from coast to coast including in Times Square, and getting on the front page of dozens of small town newspapers and in *People Magazine.* People love air cars.

But that year Terry Miller was deeply committed to his Styrofoam building project as well as trying to make a living on the side, making and selling camper shells. He had warned me on the phone that I would not only be forced to stand around for ten hours in order to get one full hour of his attention, but also that the air car was partly taken apart and therefore would not be running when I got there. None of that bothered me, so I jumped in my car and went to see Terry Miller, the first real air car advocate since General Herman Haupt CE back in the 1890s, and as an *air car advocate*—and Terry Miller himself invented the term, which is now a monument to its inventor—he is considered the founding father of the modern air car movement because he fully disclosed his air car building plans to the public, and as such he is the first air car inventor in at least 70 years to have done so, and maybe the first ever.

So I got there and Terry Miller was with his wife and a little old guy who was taking pictures. There was a real nice looking pickup truck parked in his Styrofoam building—which was arch-shaped like a Quonset hut—and as soon as I showed up he sent me and his wife over to the highway in front of the bank building to wave down a bass boat should one attempt to drive by, to take part in the photo session. We waited and waited, but a bass boat never did go by.

When the photo session was over we all went inside and Terry Miller's wife made us bologna and mustard sandwiches on Wonder Bread, and Terry said, Shoulda had a V-8, and tossed me a can of vegetable juice, and after we devoured our lunch Terry gave me his full attention for six hours and answered all my questions and let me spend an hour just looking at his air car all by myself. After that, he was down on his hands and knees fiddling with a troublesome VCR connection so he could show me the video on his then-dismantled windmill-powered compressed air station, and I started getting all apologetic since he'd done so much for me already, and he turned his head slightly toward me over his left shoulder and said, Son, I *want* to do this for you.

I had correctly quoted his air car book so much in the questions I asked that he ended up commenting that he thought I had a mind like a steel trap. I was undoubtedly the happiest air car advocate in the whole wide world on that particular day, and as I left Crestline and drove north toward Lawrence, Kansas and the University of Kansas Main Library, if I could put how I felt that evening into a pill, then that is the pill I would always want to take: the feeling you get after you have defied fear to give yourself a truly exceptional time.

And there in the card catalog room at the library was Paco, who always showed up at key moments. He said he was now a high school English teacher in Kansas City, and working on his law degree. Regarding his teaching assignment, he commented that it was not whether or not his students came to class stoned; it was *how stoned* they were when they came to class. I was just on my way out, and showed him the stack of photocopies that I clutched excitedly in my hot little hand.

That stack of photocopies, which now fills several filing cabinets, was the birth of the Pneumatic Options Research Library. It was the advent of a trend that never really stopped: the air car news just keeps getting better and better.

I had just rediscovered for the first time, in the bottom basement level of what was now my very favorite library in the whole world, an awesome collection of old compressed air textbooks, all 50 to 80 years old. I'd seen them once before but ignored them because of their age. Now it turned out that not only did I not invent the first air car—and nor did George Heaton nor Terry Miller—it was an old idea from way back: compressed air locomotives had been available commercially for at least 50 years, until the second world war. For the second time in a single blissful day, I had been to the top of Air Car Mountain, and the air car project has never been the same since that day.

On top of that, I got a fat envelope in the mail one day from a man I'd written to in Florida, a researcher like myself whose name I'd gotten from Terry Miller. In the envelope was the next amazing installment of information on real-life air cars, this time in the form of newspaper and magazine articles about inventors, many of whom—like George Heaton—claimed to be able to refill their air tanks continuously while driving through the ever-present atmosphere of Planet Earth. Although I'd come to mistrust such claims based on Terry Miller's and others' urging, the collector in me was on fire and I began my serious research years, amassing amazing and incredible confirmation that compressed air really is God's gift to man. Some things that the engineering establishment has come to believe to be a *disadvantage* of compressed air—because of our modern compulsion to cut daisies down with chain saws—is actually one of air's chief *advantages,* being misconstrued and kicked to the side without due consideration.

AIR CAR NUT ON AIR CAR MOUNTAINTOP (1985)

Meanwhile, Terry Miller called me up from Crestline, Kansas to invite me to join him for a weekend at the 1985 Energy Exposition in Wichita, where I ecstatically gave free rides on Air Car One to everyone who wanted one, for two of the happiest days of my life. The keynote speaker at the Expo was Dr. Amory Lovins, the famous author and consultant who is known world-wide for his work in energy conservation. When Dr. Lovins arrived at his hotel from the airport, Terry and I jumped on the air car and headed out into the streets of downtown Wichita to go get him and haul him over to the Expo. Terry drove like the iconoclast that he was, explaining that there are no laws to govern air cars. Dr. Lovins listened to my spiel and made some interesting suggestions, got in the passenger seat of Terry's two-seat air car, and I watched them drive away, following on foot.

Near the end of the first day, Terry was riding around the Exposition Center showing off Air Car One throughout the crowd when something went wrong with one of the rear wheel-to-axle connections and the steering went out of control. Air Car One slid harmlessly into the stage at two miles per hour and we spent the rest of the afternoon with the air car up on jack stands, staring at it with exasperation, trying to figure out a quick fix for the expediently designed and cheaply built axle mechanism. Simply put, the free wheel had seized up and, lacking a rear differential, the car could not be steered with both rear wheels fixed to the axle. Nothing witty popped into our exhausted brains, so we hung it up for the night and went to Terry's hotel room where he and his wife slept in one bed and his step-son and I slept in the other. Terry teased me for sleeping so close to the edge of the bed.

Terry was the last to climb into bed, and I noticed that he was literally snoring—I'm not making this up—*before* his head hit the pillow. You might call him the opposite of a stressed-out person. I was more worried about getting the air car running again than he was. In the morning, I was laying in bed pretending to be asleep and listening to Terry snore, when he snorted loudly a couple of times, sat up in bed and announced, "I've got it! The problem is the solution!" And he was right: all we had to do was unbolt the fixed wheel so it would spin freely on the axle, and let the frozen wheel stay fixed to the axle. With one wheel fixed and one freewheeling, the air car was repaired and drivable in less than five minutes.

Next to our booth at the Expo was a shiny little electric car which sat nearly idle through the whole show while people were lined up continuously at our booth to ride in Terry Miller's three-wheel workbench-on-wheels. People love air cars. Although Terry was fairly bored with the air car by 1985, he did exhibit one fit of mania that weekend that I will never forget. I was driving the car in big circles at the prescribed four miles per hour while Terry was off getting himself some popcorn, and when he got back with a huge sack of popcorn filled to the brim, he walked toward me and sent me hand signals indicating that I was to jump off without stopping the car. I did so, and he jumped aboard and stood up in the car—which had no body to force him to sit down—and steered with one hand while he started whooping and hollering and spilling popcorn all over the place. He pretended to be a drunk hijacker, yelling loudly in an exaggeration of his Oklahoma drawl, What kind of *air car* is this? You call this an *air car?!* A real *air car!!!* I'm driving a *real air car!*

This went on for some time until a crowd had formed, Terry's wife was ready to crawl under the table, and the supervisors of the event had gathered in a whispering circle and were shooting cold stares at the big man speeding around in warped circles, swaying like a drunk and hollering at the top of his lungs.

The last ride I gave was to a blind man who wanted a complete description of every sound he heard and everything that was going on in the air engine. I drove him around twice as long as I was supposed to, and when he got out of the car I turned off the air so he could run his hands over every part of the air engine. He intended to memorize the design so he could go home and build an air car of his own. That ride was the fulfillment of all my desires; when the man walked away with a beatific glow on his face, I walked over to Terry where he slumped in his chair at the booth, and shook his hand, explaining that I needed to go home to my wife.

THANKS, TERRY. YOU ARE THE AIR CAR DUDE! (1996)

In the meantime, I was thinking of brushing the dust off my old dream of starting a non-profit organization in order to receive tax-exempt donations to educate the world about air cars. Bigg Bangg offered to be the Executive Director of the non-profit corporation. After seeing Bigg Bangg in action, I was feeling more brave than usual about reaching out to grab some of the resources that I knew were floating around loose in the world, but that I had always avoided for fear that people would laugh in my face for asking. I also knew that Terry Miller had built his new *Spirit of Joplin* air cars almost entirely from parts donated by companies who wanted nothing more in return than to have their company's name stenciled on the side of the air car.

Then Terry had given the whole project away to his partner and one of his children, and in a few months he was dead.

I remember back when I lived in Eugene, my correspondent in Florida had tracked me down to tell me with great excitement about Terry's new air cars. I found articles about The *Spirit of Joplin* in several serious technical journals. I wrote Terry a letter, and he wrote back, sending me photos of the engine, tapes describing how it was built, a video, and $185—which I hadn't asked for—as a fee for advertising his "info-pack" in my Pneumatic Options Research Library catalog. He told me in his letter to call him sometime, preferably around three or four o'clock in the morning, since he was diabetic and that's when he always woke up to pee.

I couldn't believe that the mighty Terry Miller really wanted me to call him that time of the night, but one night I got up the nerve to do it. He picked up the phone and said, Hello. Rather sleepily I thought.

Hi, Terry, this is Scott Robertson.

I heard Terry's wife muttering something in the background, and he put his hand over the receiver and said, "Honey! *It's Scott Robertson!"* like I was *somebody* or something. *It's Scott Robertson!*

Excuse me while I indulge myself: *It's Scott Robertson!*

Thanks, Terry.

THIS AIR CAR WEBSITE AND ALL MY AIR CAR WEBSITES ARE DEDICATED TO MR. TERRY MILLER, UNTIL SUCH TIME AS SOMEONE ELSE COMES ALONG AND DOES A BETTER JOB THAN HE DID OF INSPIRING ME AND OTHERS TO MAKE AIR CARS A REAL HAPPENING ON THIS PLANET

THANKS, TERRY!

Email: misteraircar@lycos.com

United States Patent [19]

Miller

[11] **4,370,857**

[45] **Feb. 1, 1983**

[54] **PNEUMATIC SYSTEM FOR COMPRESSED AIR DRIVEN VEHICLE**

[76] Inventor: **Terry R. Miller**, Box 80, Crestline, Kans. 66728

[21] Appl. No.: **167,524**

[22] Filed: **Jul. 11, 1980**

[51] **Int. Cl.**³ **F60D 31/02**

[52] **U.S. Cl.** **60/413**; 91/188; 180/165; 180/215; 180/302

[58] **Field of Search** 180/302, 165, 215; 60/414, 370, 371, 374, 413; 91/152, 153, 159, 188, 236, 237, 239

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3,980,152	9/1976	Manor	180/302 X

Primary Examiner—Douglas C. Butler
Assistant Examiner—Donald W. Underwood
Attorney, Agent, or Firm—Harvey B. Jacobson

[57] **ABSTRACT**

An air driven vehicle utilizes pressurized air contained in storage tanks for actuating double-acting cylinders which in turn transmit a driving force to an axle of the vehicle. The compressed air in a first air tank under high pressure is fed to a first actuating cylinder so as to drive a crank which operates a main drive gear in communication with an axle gear attached to the vehicle axle. Upon a reversal of movement of the piston contained in the first actuating cylinder, a supply of exhaust air is directed from the cylinder to a second air pressure tank in which the exhaust air is collected under a lower pressure than the air contained in the first air pressure tank. The exhaust air is prevented from flowing back into the first actuating cylinder through the use of a one-way check valve, and the pressurized exhaust air in the second pressure tank may then be used to impart a driving force to a second actuating cylinder attached to the same crank so as to provide a supplementary force to the main drive gear in propelling the vehicle. The air exhausted from the second actuating cylinder during the return stroke of a piston in the cylinder may then be similarly employed to drive even additional actuating cylinders or may be exhausted to the atmosphere.

5 Claims, 8 Drawing Figures

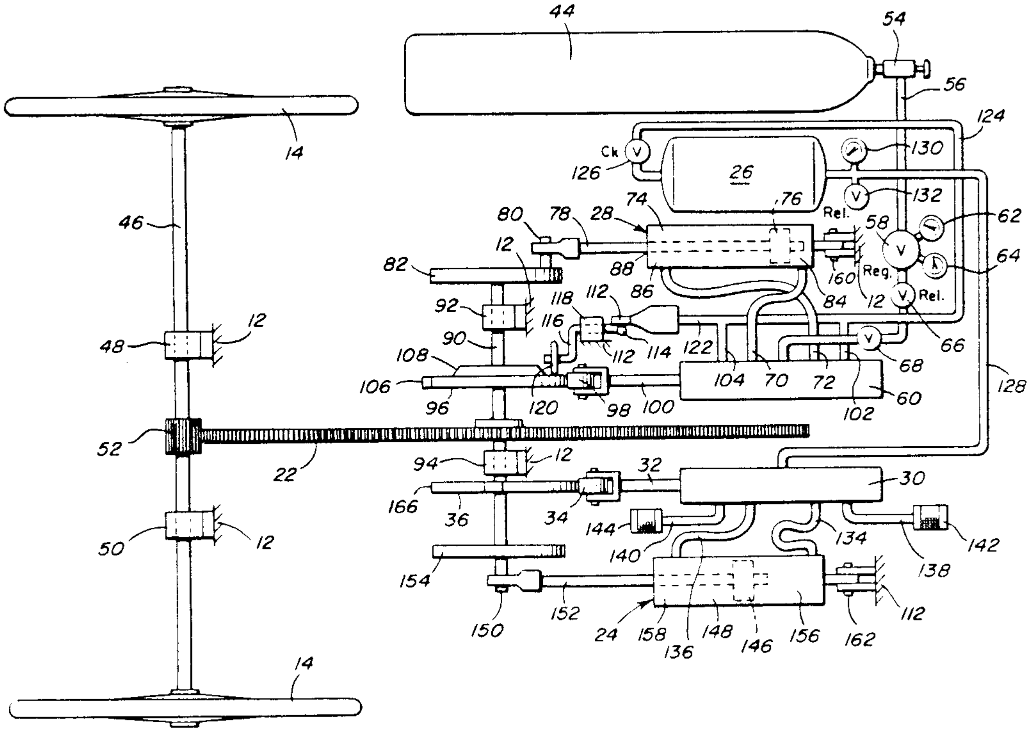


Fig. 1

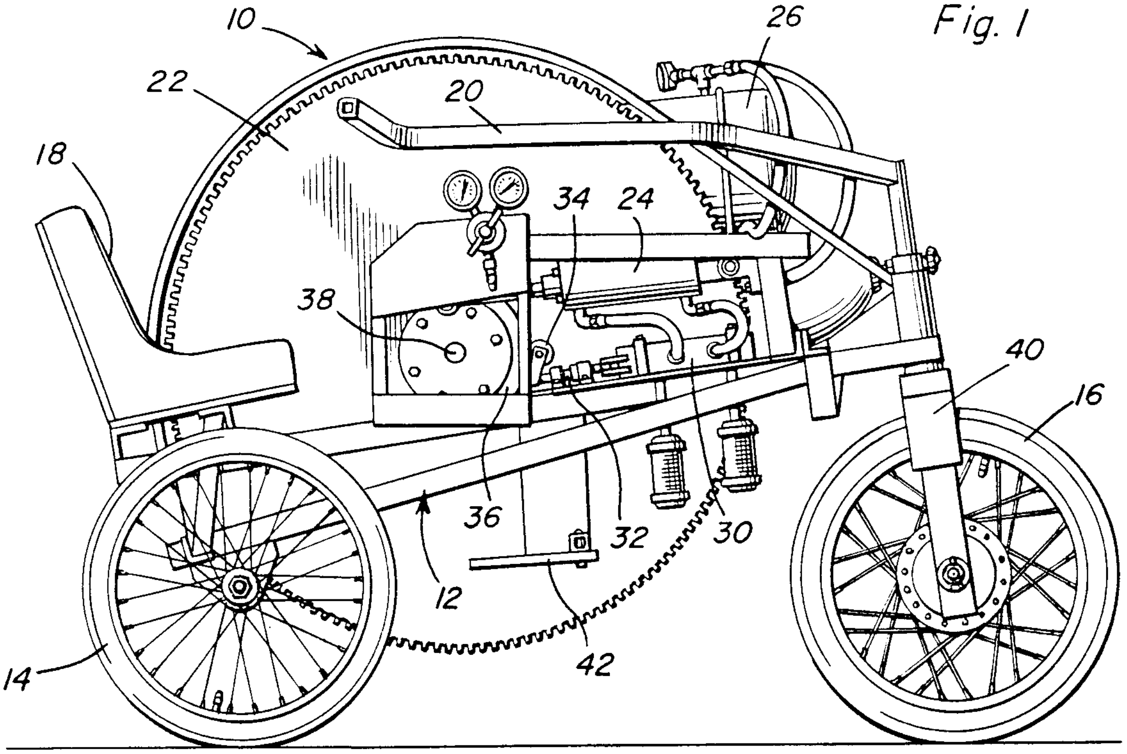
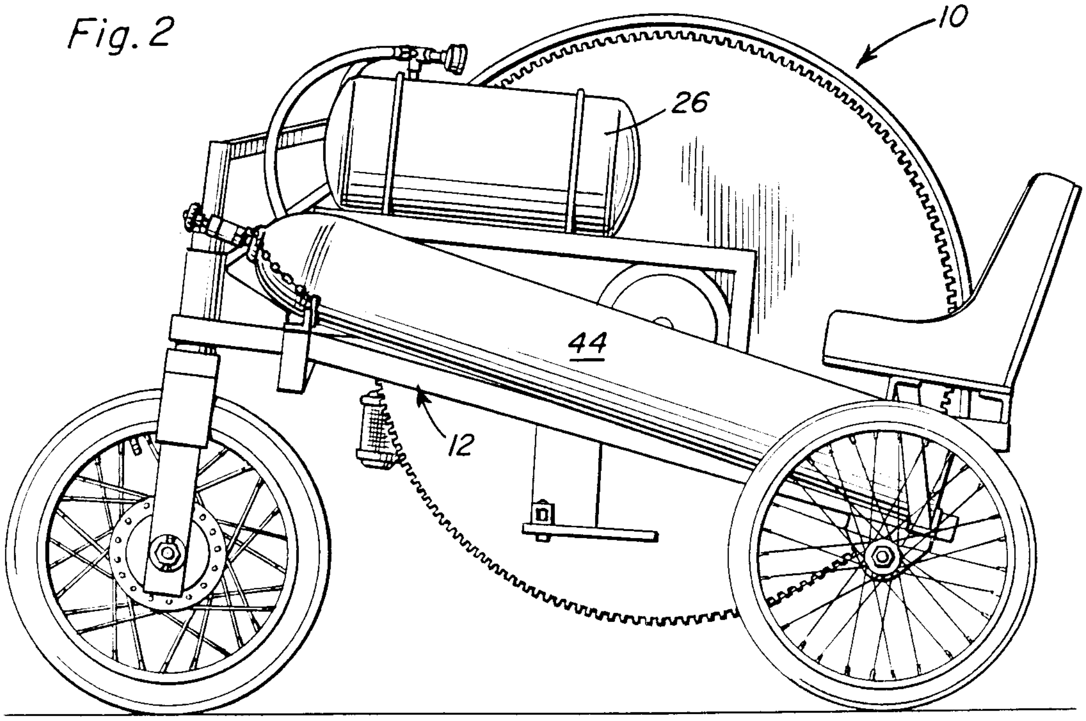


Fig. 2



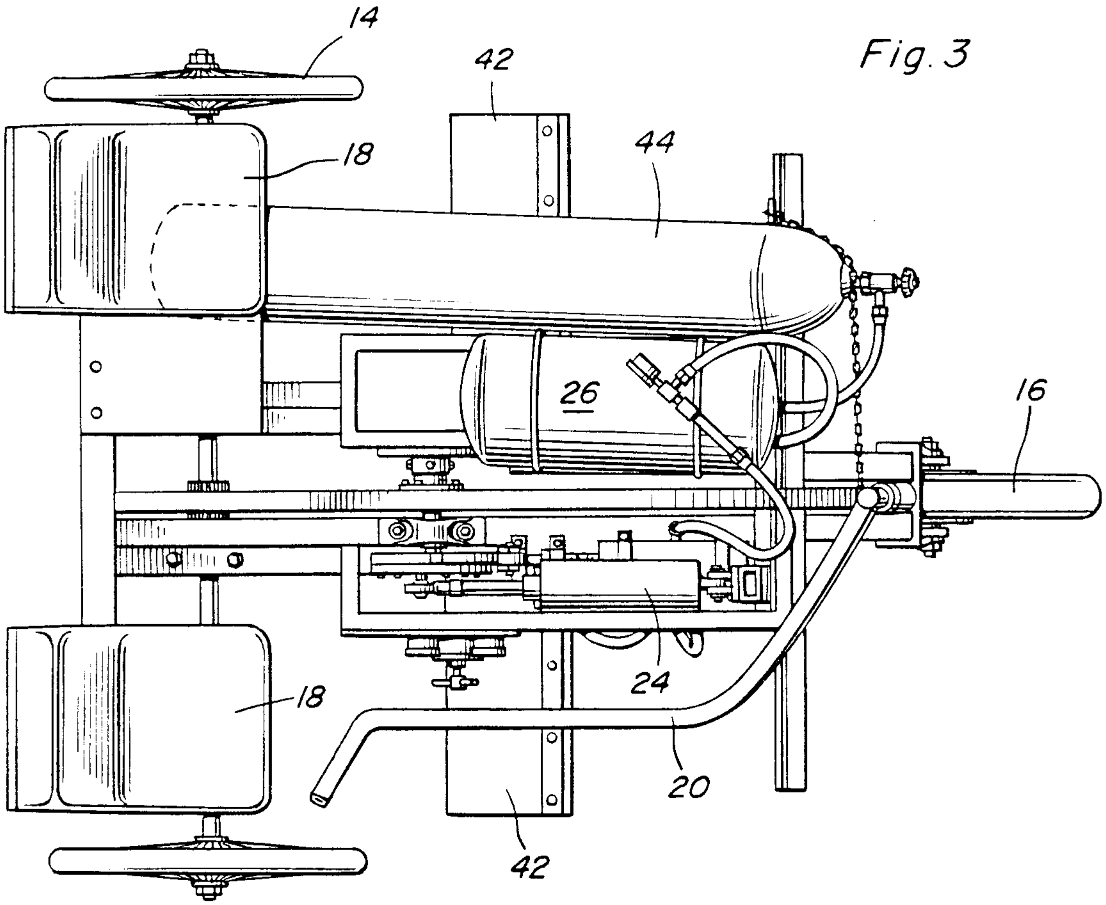


Fig. 3

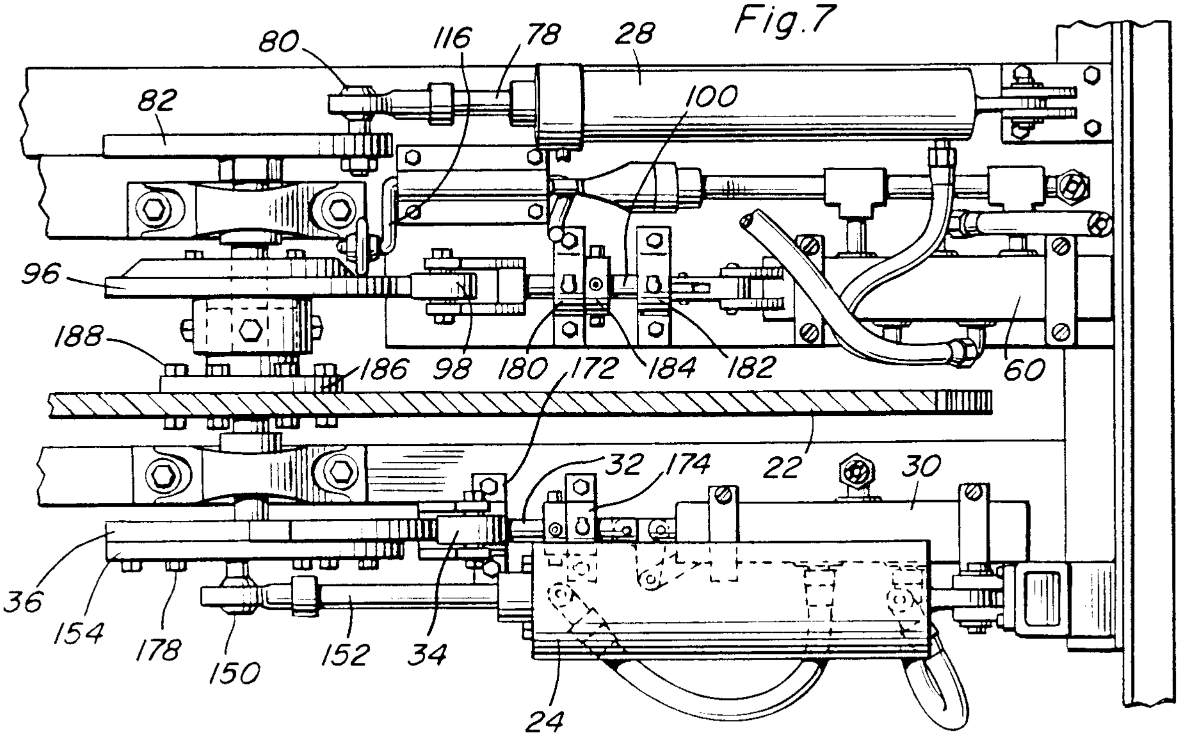


Fig. 7

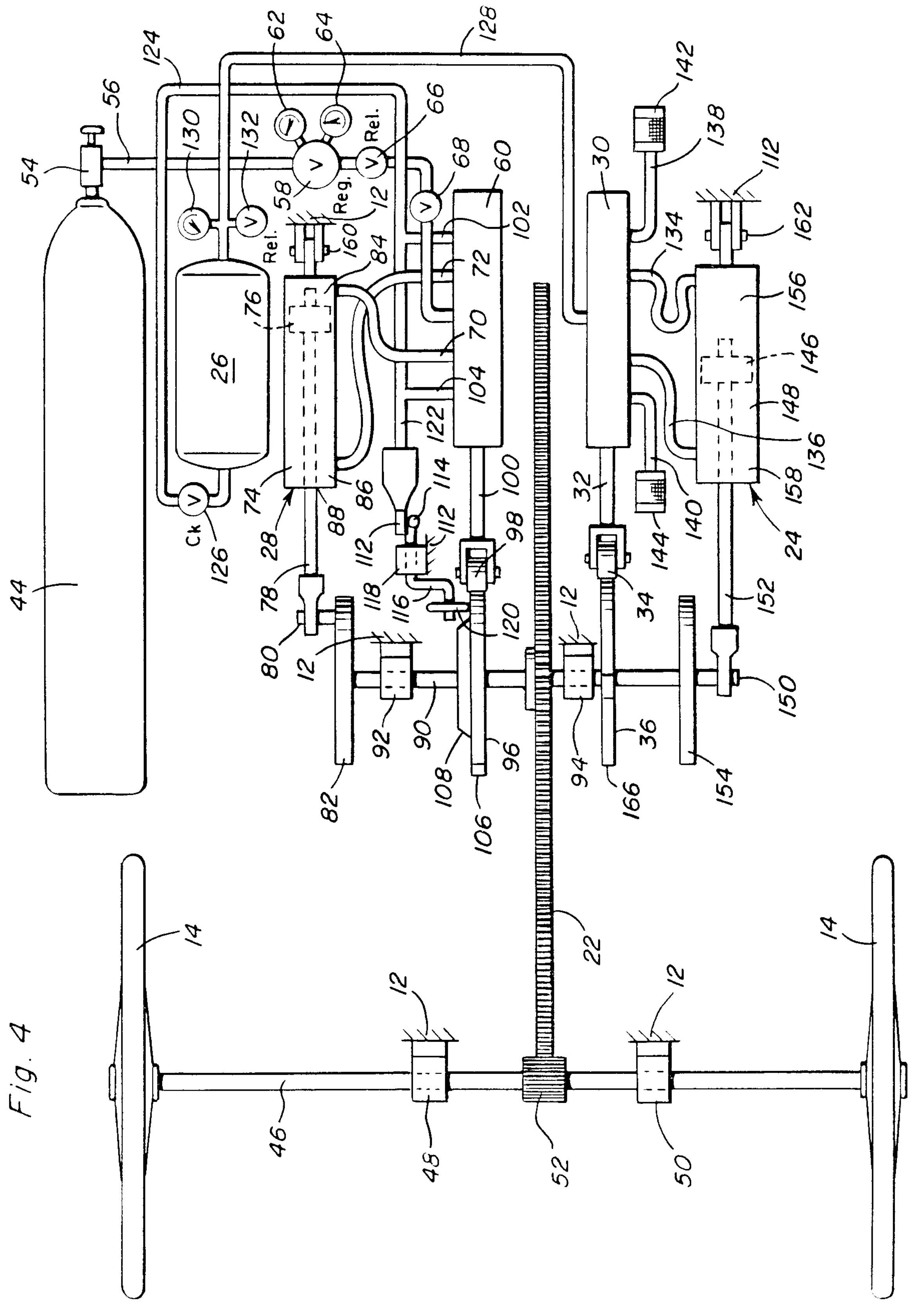

Reg.
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Fig. 4

Fig. 5

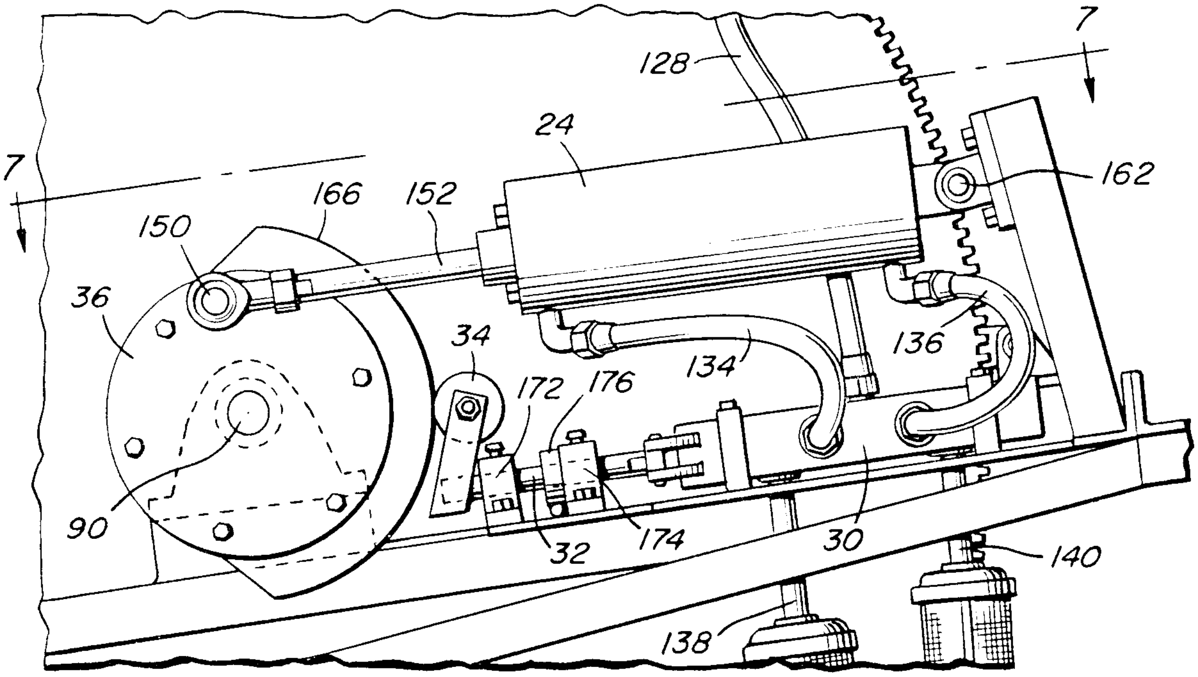
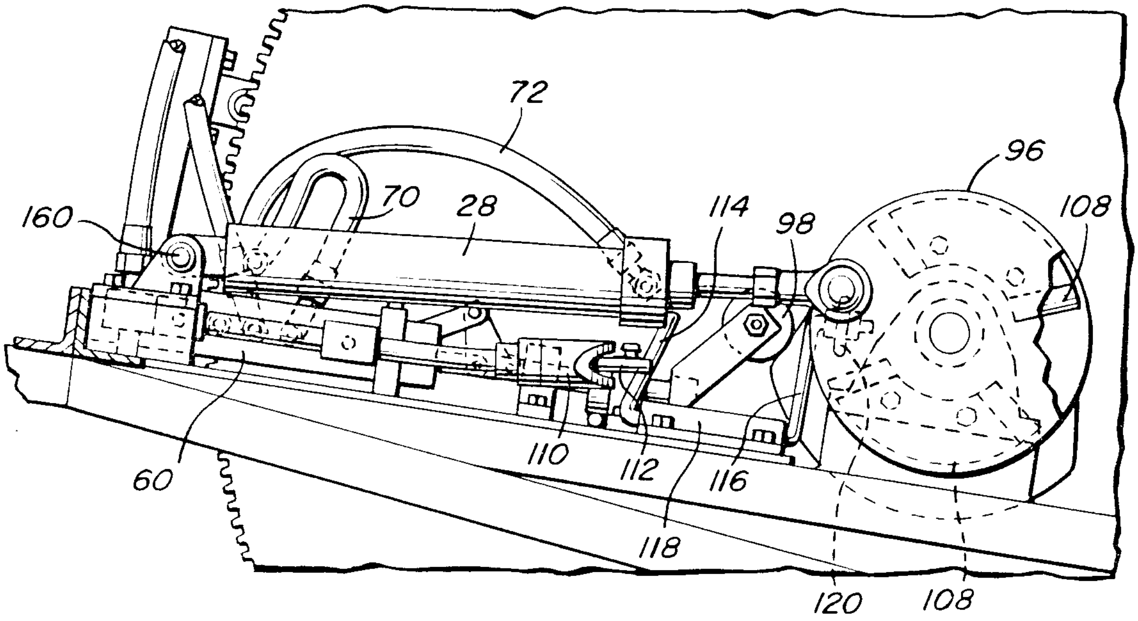


Fig. 6



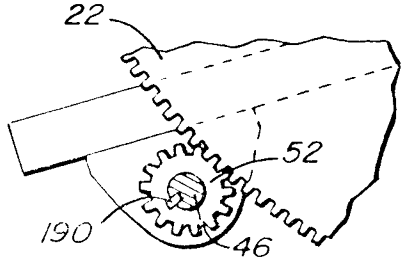


Fig. 8

PNEUMATIC SYSTEM FOR COMPRESSED AIR DRIVEN VEHICLE

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to air-driven vehicles and more particularly pertains to pneumatic system for propelling a compressed airdriven vehicle which utilizes a first source of compressed air to operate a first actuating cylinder operable to propel the vehicle and which utilizes the exhaust air from the first actuating cylinder as a source of compressed air to operate a second actuating cylinder which supplements the driving force of the first actuating cylinder.

2. Description of the Prior Art

In the field of air driven vehicles, it has been the general practice to employ a source of compressed air to operate an air actuating cylinder which through its operation propels the vehicle. Such devices have generally proven to be unsatisfactory in operation due to the gross inefficiency associated therewith. Specifically, the tremendous weight involved in the construction of these vehicles, as well as the large amount of compressed air required to propel these vehicles even for a short distance, has made the construction of the same an impractical matter. Many of the problems associated with air vehicle construction have revolved around the fact that a tremendous amount of compressed air is necessary for each rotation of a drive shaft, and as such, those concerned with the development of air-driven vehicles have long recognized the need for either decreasing the amount of compressed air required for any single revolution of a drive shaft or, in the alternative, making more efficient use of the amount of compressed air being employed.

Accordingly, the development of air-driven vehicles has been a slow process and to date, these vehicles have not been regularly employed as a means of transportation, although they apparently were conceived as far back as in the late 19th century. For example, U.S. Pat. No. 331,276, issued Dec. 1, 1885, to Buell, discloses a tricycle having an engine operable by compressed air attached thereto so as to provide a propelling force to the tricycle. In this respect, cylinders of compressed air were illustrated as being operably connected to cranks associated with the tricycle axle by means of air actuated cylinders. However, no mention of, or provision for, a further use of the actuating air being exhausted from the actuating cylinders is made. Similarly, U.S. Pat. No. 589,710, issued Sept. 7, 1897, to Flucks, discloses the use of compressed air or other compressed fluid being conveyed to drive wheels so as to impart movement to a carriage. As with the Buell device, the propelling compressed air is used but one time to impart its driving force and then is exhausted to the atmosphere.

In that the above-discussed compressed air vehicles were totally impractical, a number of attempts have evolved to make more efficient use of the compressed air employed as the driving medium, as well as to provide supplementary propelling forces for use in conjunction with the drive-imparting compressed air. For example, U.S. Pat. No. 3,704,760, issued Dec. 5, 1972, to Maruyama, discloses a propelling system for vehicles utilizing both an air driven motor and an electric motor. the air driven motor is operated by air supplied under pressure from a source of compressed air, such as a cylinder or a liquid-air tank, while the electric motor is driven by a storage battery in which stored electrical energy produced by a generator may assist in the propelling of the vehicle. In this respect, the generator is allegedly driven by a turbine operated by the air supplied under pressure from the source of compressed air, while both the air driven motor and the electric motor are connected to transmission means linked to the driving wheels of the vehicle. In this respect, the Maruyama propelling system utilizes the compressed air to both drive the vehicle and to generate electricity for also driving the vehicle. As can be appreciated, an even greater supply of compressed air would be needed than with a vehicle driven exclusively by compressed air, and accordingly, the problems of vehicle weight and reduction of compressed air requirements are not solved by this construction. Further, no suggestion or teaching is present regarding the use of exhausted compressed air as a source of further energy to propel the vehicle.

U.S. Pat. No. 3,847,058, issued Nov. 12, 1974, to Manor, is even more representative of the many futile attempts to develop an efficient air powered vehicle. In this respect, Manor discloses a vehicle having an air powered engine which utilizes a first reservoir of gaseous fluid under pressure connected to an intake system for operating the engine. A second reservoir is connected to an exhaust system for receiving the spent air, and a suspension-type compressor is operatively connected between a wheel and the chassis whereby relative vertical motion between the wheel and the chassis will cause operation of the compressor. Further, additional compressors are operated primarily from air flow induced by forward motion of the vehicle, and the air from all of the aforementioned compressors is then redirected through the system to again power the vehicle. In effect, the vehicle described therein is exceedingly complex and is apparently directed toward a vehicle which would effectively power itself. At the same time, the exhaust air from the actuating cylinder is not utilized to drive a second separate actuating cylinder, and along the same line of reasoning, the compressed air deliverable to the actuating cylinder is used only one time for imparting a propelling force to the vehicle before it is returned to a storage tank for reuse.

Similarly, U.S. Pat. No. 3,925,984, issued Dec. 16, 1975, to Holleyman, discloses a compressed air power plant for use on a vehicle which utilizes the compressed air to operate actuating cylinders for providing the propelling force necessary to drive the vehicle. The vehicle is further provided with a compressor which is battery operated and which serves to continually supply compressed air to storage tanks so that the vehicle effectively never runs out of compressed air for propulsion, but is limited in its operation only by the extent of the power supplied by the batteries. In other words, once the batteries are expended, the compressor ceases to function and the compressed air supply is exhausted. While this disclosed system may be somewhat practical in nature, it still does not make efficient use of the compressed air utilized, since no means are provided for obtaining energy from the exhausted air.

Along the same line of operation, there is disclosed in U.S. Pat. No. 3,765,180, issued Oct. 16, 1973, to Brown, a compressed air engine used in combination with an auxiliary air compressor for building up the pressure in a compressed air supply tank which feeds air through an engine control valve to the engine pistons. Upon reaching a minimum air pressure, an electric motor is cut off and the auxiliary compressor is simultaneously engaged with the crankshaft to continue to build up air pressure. Also provided is a main recycle air compressor for capturing and reusing exhausted air and supplying the same back to the compressed air supply tank. As can be appreciated, the Brown device relies on a plurality of compressors as part of the system, as well as an electrical supply for driving the same. Again, no mention is to be found of utilizing exhaust air as a compressed air supply for operating a second actuating cylinder. Further, it is readily apparent that vehicles utilizing concurrent supplies of electrical energy are by necessity of a much heavier construction due to the positioning and transporting of batteries, compressors, alternators, etc., thereon.

There has been at least one attempt to devise an operable system for utilizing exhaust air as an independent propulsion medium for operating additional actuating cylinders. In this respect, U.S. Pat. No. 3,666,038, issued May 30, 1972, to Hudspeth et al, discloses a system utilizing a pressure storage vessel for initially charging a first air cylinder of a series of air cylinders. Valve means are disclosed which admits a flow of pressurized air, in a sequential manner, into the cylinders for piston movement thereby to compress spring members to a loaded condition. Additional valve means, closed during downward piston movement, are subsequently actuated to permit dischage of an air impulse by action of the compressed springs combined with a second source of air pressure acting on the other side of the respective pistons. The last cylinder of the series is operable to impart a force to a media for the operation of a motor powering a vehicle. In this connection, only the last cylinder is used to impart a driving force to a vehicle, since the use of the difference size cylinders is strictly for the purpose of increasing pressure, and no use or suggestion is made to save exhaust air at a lower pressure to use again in another larger cylinder to obtain almost the same force each time the air is reused and to have each cylinder used so as to individually impart a driving force to the vehicle.

SUMMARY OF THE INVENTION

The general purpose of the present invention, which will be described subsequently in greater detail, is to provide for an air-driven engine that has all of the advantages of similarly employed prior art devices and has none of the above-described disadvantages. To obtain this, the present invention provides for a vehicle which is powered by at least two air operated double-acting actuating cylinders, such cylinders being operably connected to a main drive gear which is in turn meshed with an axle gear fixedly secured to an axle having driving wheels thereon. A high pressure air tank supplies air to an air timing valve which in turn directs the air to a first actuating cylinder thereby supplying a first source of propulsion to the main drive gear. The timing valve during spaced intervals directs the exhausted air being released from the first actuating cylinder to a pressure accumulator in the form of a low pressure supply tank for collection and compression therein. In this respect, a one-way check valve is provided in the line to the low pressure air tank so as to prevent the compressed air contained in the tank from flowing backward in a manifold to the air timing valve. Through the use of a second air timing valve, the compressed exhaust air contained in the low pressure air tank may be directed to a second larger actuating cylinder operated in 90° out-of-phase relation to cylinder **28** so as to present a second propulsion force to the main drive gear thereby to drive the vehicle. Once the air is exhausted from the second actuating cylinder, it may be directed to the atmosphere or, alternatively, it may be directed to even further supply tanks and actuating cylinders.

While the general operation of the present invention has been described, it should be noted that the first air timing valve is further operably connected to a vent valve which is cam operated and which serves to vent exhaust air coming from the first actuating cylinder to the atmosphere between the spaced intervals aforementioned. In this respect, the vent valve operates during those periods of time when the back pressure associated with the exhaust chamber would serve to disrupt the efficiency of the drive connection as related to the positioning of a crank throw associated with the drive shaft. In other words, the back pressure is tolerated during only those parts of the drive cycle when maximum torque and efficiency is available to the drive shaft containing the main drive gear so that the exhaust air back pressure does not seriously hamper the propulsion force being supplied to the drive wheels.

It is, therefore, an object of the present invention to provide a new and improved air-driven vehicle which has all of the advantages of the prior art and none of the disadvantages.

It is another object of the present invention to provide for an air driven vehicle which makes efficient use of its propelling compressed air supply.

A further object of the present invention is the provision of a lightweight air driven vehicle.

Still another object of the present invention is the provision of an air driven vehicle which utilizes exhaust air from a first driving cylinder as an actuating means for a second driving cylinder.

Yet another object of the present invention is the provision of a novel valve system which permits the capturing of some exhaust air from an actuating cylinder for use in propelling a second actuating cylinder and which further permits the release of some of the exhaust air to the atmosphere during parts of a driving cycle when the capturing of the exhaust air would present a back pressure problem affecting engine output.

These together with other objects and advantages which will become subsequently apparent reside in the details of construction and operation as more fully hereinafter described and claimed, reference being had to the accompanying drawings forming a part hereof, wherein like numerals refer to like parts throughout.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a right side elevation view of a preferred embodiment of the air-driven vehicle forming the present invention;

FIG. **2** is a left side elevation view of the air-driven vehicle illustrated in FIG. **1**;

FIG. **3** is a top plan view of the air-driven vehicle illustrated in FIG. **1**;

FIG. **4** is a schematic illustration of the pneumatic system employed in driving the air-driven vehicle shown in FIG. **1**;

FIG. **5** is a detailed structural view of a second actuating cylinder which is operated by exhaust air supplied by a first actuating cylinder;

FIG. 6 is a detailed structural view of the first actuating cylinder and structure associated therewith;

FIG. 7 is a partial top plan view taken along the line 7--7 of FIG. 5 looking in the direction of the arrows and illustrating some of the detailed structure associated with the first and second actuating cylinders; and

FIG. 8 is a detailed structural view of the connection between the main drive gear and the axle gear operably associated therewith.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to the drawings and, in particular, to FIG. 1 wherein there is illustrated in perspective a right hand elevation view of the air-driven vehicle and pneumatic system associated therewith forming the present invention and generally designated by the numeral **10**. In this respect, the vehicle **10** essentially comprises a vehicle frame **12** to which is connected a pair of driving wheels **14** and a front steering wheel **16** thereby forming a tricycle-type construction. A seat **18** is conventionally mounted to the vehicle frame **12** and is so positioned whereby an operator may be seated thereon in a manner providing easy access to the steering handle **20**. The steering handle **20** is fixedly attached to the steering wheel **16** in a conventional manner whereby movement of the steering handle, which is similar to the handle bars found on a bicycle, is translated to the steering wheel **16** thereby to govern the direction of movement of the vehicle **10**.

Also illustrated in FIG. **1** is the main drive gear **22**, which is utilized to provide a driving force to the driving wheels **14**, and the secondary double-acting actuating cylinder **24** which serves as one of two driving cylinders for operating the main drive gear. In this connection, the secondary actuating cylinder **24** is driven by compressed air supplied from a low pressure compressed air tank **26**, such low pressure tank being supplied with the exhaust air from a primary double-acting actuating cylinder **28** (not illustrated in this figure). The air from the low pressure compressed air tank **26** is selectively directed to the secondary actuating cylinder **24** by means of a secondary air timing valve **30** which is operable in response to the reciprocable movement of a spool member **32** having a skate wheel or cam follower **34** attached thereto and engaging with a secondary cam **36**. The seconday cam **36** is fixedly attached to a drive shaft **38** to which is also fixedly attached the main drive gear **22**.

Other structural features mentionable with respect to the embodiment illustrated in FIG. **1** include a conventional shock absorber **40** associated with the steering wheel **16** and operably connected to the frame **12**. Additionally, one of a pair of foot rests **42** is illustrated upon which an operator may position his feet during a driving of the vehicle **10**.

FIG. **2**, which is a left side elevation view of the present invention as opposed to the right side elevation view illustrated in FIG. **1**, shows the compressed air storage means utilized for propelling the air-driven vehicle **10**. In this respect, a storage pressure source such as a high pressure compressed air tank **44** is shown fixedly attached to the frame **12**, such high pressure compressed air tank supplying compressed air to the aforementioned primary double-acting actuating cylinder **28**. Similarly, the low pressure compressed air tank **26** is shown mounted on the vehicle **10** in a position proximate to and above the high pressure compressed air tank **44**. The low pressure compressed air tank **26** utilizes exhaust air from the primary double-acting actuating cylinder **28** and stores the same until use in the secondary double-acting actuating cylinder **24**.

FIG. **3** further illustrates the general layout and structural configuration of the air-driven vehicle **10** by illustrating the same in terms of a top plan view. In this connectin, it can be seen that the vehicle may utilize a pair of seats **18** so as to accommodate two operators, while the operator on the right steers the vehicle by means of the steering handle **20** which controls movement of the steering wheel **16**. As shown, the air-driven vehicle **10** is basically of a symmetrical construction with the high pressure compressed air tank **44** and the low pressure compressed air tank **26** being positioned on the non-steering side of the vehicle.

Reference is next made to FIG. **4**, which is a schematic diagram of the pneumatic system utilized in operating the air-driven vehicle **10**, whereby a first discussion may be presented regarding the method and means utilized for operating the present invention. In this respect, it can be seen that the drive wheels **14**, as priorly discussed, are fixedly attached to the drive axle **46** which is in turn secured to the vehicle frame **12** by means of a pair of bearing supports **48**, **50**. A driving force may be imparted to the drive axle **46**, and thus to the drive wheels **14** so as to propel the air-driven vehicle **10**, through the use of an axle gear **52** concentrically aligned with and fixedly attached to the axle. As shown, the axle gear **52** is drivingly engaged with the main drive gear **22**, and as can be appreciated, any movement of the main drive gear will be transferred to the axle gear **52** so as to propel the vehicle **10**. Movement of the main drive gear **22** is effected through the use of the primary double-acting actuating cylinder **28** and the secondary double-acting actuating cylinder **24**.

With respect to the initial structural layout illustrated in FIG. **4** and without a description of the operation thereof at this point of discussion, it can be seen that the high pressure compressed air tank **44** is provided with a faucet type valve **54** which controls the delivery of compressed air to a primary air manifold **56**. The manifold **56** has a regulator **58** operably connected thereto, such regulator serving to regulate the pressure and amount of compressed air being supplied to a primary air timing valve **60**. The regulator **58** includes an air tank pressure gauge **62**, which indicates the pressure of the compressed air being supplied to the regulator from the high pressure compressed air tank **44**, and a regulated air pressure gauge **64**, which indicates the pressure of the compressed air leaving the regulator and being supplied to the primary air timing valve **60**. Additionally, a safety release valve **66** is provided in the manifold **56** downstream of the regulator **58** so as to provide a means for venting the high pressure compressed air in the event of a failure of the regulator. Further, an on-off control valve **68** is provided in the manifold **56** which serves as a second means of cutting off the supply of compressed air from the high pressure air tank **44**, the first means being the faucet valve **54**.

Operably attached between the primary air timing valve **60** and the primary double-acting actuating cylinder **28** are a pair of conduits **70**, **72** which serve to alternately supply and exhaust compressed air to and from the actuating cylinder. In this connection, the primary air timing valve **60** is a spool-type directional valve provided with four-way operation and being cam operated, such valves being well-known and commercially available.

The primary double-acting actuating cylinder **28** includes a cylinder housing **74** into which is positioned a drive piston **76**. The piston **76** is provided with a connecting rod **78** which is rotatably attached to a ball joint or crank pin **80** provided on a crank **82**. The drive piston **76** is sealingly positioned within the cylinder housing **74** in such a manner that air may be compressed on either side of the piston, i.e., either in the spaces **84** or **86**. As such, the connecting rod **78** projects out of the cylinder housing **74** through an aperture **88** which is of substantially the same diameter of the connecting rod so as to provide an effective seal between the space **86** and the atmosphere.

The crank **82** is fixedly attached to a main power transmitting drive shaft **90**, such shaft being rotatably supported from the vehicle frame **12** by a pair of bearings **92**, **94** and further having the main drive gear **22** concentrically aligned with and fixedly attached thereto.

Also fixedly attached to the main drive gear shaft **90** is a primary air timing valve cam **96** which rotates concurrently with the shaft **90** and which is in operable engagement with a cam follower **98**. The cam follower **98** is operably attached to a spool shaft **100**, such spool shaft being reciprocable within the primary air timing valve **60** and serving to position the plurality of spool valves contained therein so as to control air flow to conduits **70** and **72**, as well as to conduits **102** and **104**.

The primary air timing valve cam **96** has a first cam surface **106**, which engages the cam follower **98**, and a second cam surface **108**, which serves as a pig valve actuating cam. In this respect, a conventional pig valve **110** is utilized such as a Trojan model 75 manufactured by Ritchie Industries, Inc. of Conrad, Iowa. Such an automatic pig drinking valve is modified to operate as a lever operated vent to the atmosphere, is positioned as illustrated so as to be operable in response to movement of the primary air timing valve cam **96**. One example of such a pig valve is disclosed in U.S. Pat. No. 3,646,955 to Olde. Specifically, the pig valve **110** is actuated by a lever **112** which may be displaced sideways out of alignment with the longitudinal axis of the valve so as to cause the valve to vent to the atmosphere, and this sideways movement of the lever is effected by the movement of an abutting lever **114** integrally attached to a bell crank **116**. The bell crank **116** is rotatably attached to the vehicle frame **12** by means of a bearing **118** and is rotatable within the bearing in response to the movement of a bell crank follower **120** which is in an abutting relationship with the primary air timing valve cam **96**. The bell crank follower **120** is engageable with the second cam surface **108** so as to effect the aforedescribed rotation of the ball crank **116** within the bearing **118** so as to cause the abutting lever **114** to displace the pig valve lever **112**, thereby venting the same to the atmosphere.

The pig valve **110** is in communication with the conduits **102**, **104** through a branch conduit **122** and serves to release exhaust air pressure contained in a pressure equalization transfer—midstroke/venting—pumped pressure transfer manifold **124**, the purpose of which will be subsequently described. In this connection, exhaust air from the primary double-acting actuating cylinder **28** may at selective times be either vented to the atmosphere, through the operation of the pig valve **110**, or to the low pressure compressed air tank **26**, depending on the positioning of the primary air timing valve cam **96**. As such, it can be appreciated that the low pressure compressed air tank **26** receives its entire supply of compressed air from the primary air timing valve **60**, such compressed air supply comprising the exhaust air being ejected from the primary double-acting actuating cylinder **28**.

A one-way check valve **126** is provided in the transfer manifold **124** whereby exhaust air may be directed from the air timing valve **60** into the low pressure compressed air tank **26** but may not flow backward from the tank towards the air timing valve. Effectively then, the low pressure compressed air tank **26** serves as a collection and storage means for exhaust air being admitted from the actuating cylinder **28**, such exhaust air then being suppliable to the secondary air timing valve **30** by means of a pressure hose or conduit **128**. A pressure gauge **130** is provided in the conduit **128** so as to provide an indication of the air pressure being supplied to the secondary air timing valve **30**, and a pressure relief valve **132** is also provided therein in case the pressure within the conduit becomes excessive to the point of danger of injury to an operator or damage to the vehicle **10**.

The secondary air timing valve **30** is also a spool-type directional valve having four-way operation and is provided with a pair of conduits **134**, **136** which alternately direct compressed air to and from the secondary double-acting actuating cylinder **24**. Additionally, a pair of conduits **138**, **140** exhaust directly to the atmosphere and are provided respectively with mufflers **142**, **144**.

The secondary actuating cylinder **24** is of a larger construction than the primary actuating cylinder **28** and includes a piston **146** positioned within a cylinder housing **148** and being operably attached to a second crank pin or ball joint **150** by means of a connecting rod **152**. The crank pin **150** is fixedly attached to a second crank **154** which, along with the first crank **82**, is fixedly attached to the main drive gear shaft **90**. The secondary actuating cylinder **24** has spaces **156**, **158** positioned on respective sides of the piston **146**, these spaces being respectively in communication with the conduits **134**, **136**. As such, both the primary actuating cylinder **28** and the secondary actuating cylinder **24** are drivingly engaged with the main drive gear shaft **90** so as to effect a rotation thereof in response to the reciprocable movement of the pistons **76**, **146**, within the respective actuating cylinders. Since the rotating movement of the cranks **82**, **154** results in some oscillatory movement of the actuating cylinders **28**, **24**, respectively, each of the actuating cylinders are pivotally attached to the vehicle frame **12**. In this connection, the actuating cylinder **28** is attached to the vehicle frame **12** about a pivotal connection **160**, and the actuating cylinder **24** is attached to the vehicle frame by means of a pivotal connection **162**.

Similar to the operation of the primary air timing valve **60**, the secondary air timing valve **30** is likewise cam operated by means of a secondary air timing valve cam **36** which is fixedly attached and rotatable with the main drive gear shaft **90**. The secondary air timing valve cam **36** is provided with a cam surface **166** against which a cam follower **34** is engageable, such cam follower being fixedly attached to a spool shaft **32** which is reciprocable within the secondary air timing valve **30** so as to control the flow of air through the conduits **134**, **136**, **138** and **140**.

A better understanding of the pneumatic drive system illustrated in FIG. **4** can be ascertained through a discussion of the operation thereof. In this connection, compressed air contained in the high pressure compressed air tank **44** flows therefrom through faucet valve **54** and thence through the manifold or conduit **56** to the regulator **58**. In flowing through the regulator **58**, the air pressure is regulated as to a desired pressure selected by the vehicle operator. In this respect, regulation of the pressure is afforded by observing the pressure of the air contained in the tank **44** through viewing the pressure gauge **62** and by adjusting the regulator **58** so as to obtain a desired outlet pressure therefrom as indicated by the regulated air pressure gauge **64**. The regulated pressure should not be allowed to exceed the rated pressure capacity of the primary double-acting actuating cylinder **28**, the primary air timing valve **60**, the on-off valve **68** or the conduits connecting them. However, should the regulated pressure somehow be allowed to exceed the rated pressure capacity of any of these parts, the safety release valve **66**, which is installed between the regulator **58** and the on-off valve **68**, will serve to release the excess air pressure thereby preventing any damage to the system or injury to a vehicle operator. In this connection, the pressure relief valve **66** should be set above the rated pressure of the primary actuating cylinder **28**.

With further reference to FIG. **4**, it can be seen that the regulated pressure compressed air is conducted from the regulator **58** through the on-off valve **68**, which normally will be a three-way valve designed to vent downstream air to the atmosphere when in an off position, into the primary air timing valve **60**. As afore-described, the primary air timing valve **60** is a four-way spool valve having tapped exhaust ports for pipe fittings with a closed center position. The timing valve **60** is cam operated utilizing a return spring and is designed to control the flow of compressed air to and from the actuating cylinder **28**. A first pair of conduits **70**, **72** are provided for communicating the air timing valve **60** with the primary actuating cylinder **28** and, with respect to the positioning of the parts shown in FIG. **4**, it can be appreciated that a supply of compressed air provided through the conduit **70** will tend to pressurize the space **84** defined by the cylinder housing **74** and the piston **76**, thereby to effect a movement of the piston and associated connecting rod **78** in a direction towards the crank pin **80**. At any given time in operation, one of the two conduits **70**, **72** is supplying a path for regulated air pressure to move the cylinder piston **76**, while at the same time the other conduit is providing a path for exhaust air or air that has already been used against the piston, to provide motive power. As such then, during a supplying of compressed air through the conduit **70**, the conduit **72** provides an open path for air contained in the space **86** to flow outwardly therefrom and into the air timing valve **60**. As is then apparent, both conduits **70**, **72** can never supply motive air pressure to the actuating cylinder **28** at the same time nor can they carry exhaust air at the same time, i.e., each conduit connecting a port of the actuating cylinder to a port of the timing valve **60** will either be provided a path for the regulated (motive air pressure) or a path for exhaust air pressure.

As shown then, a pressurization of the space **84** with a concurrent exhausting of the space **86** will effect a rotatable movement of the crank **82**, since the connecting rod **78** is rotatably attached to the crank pin **80** which in turn is fixedly attached to the crank. The crank **82**, as illustrated in FIG. **4**, is at its point of rotation referred to as dead center and it is at this point that the air timing valve **60** acts to change the duties being performed by the conduits **70**, **72** from pressure to exhaust for the one and from exhaust to pressure for the other, so that the actuating cylinder **28** alternately pushes and pulls to thereby rotate the crank **82**. The double-acting actuating cylinder **28** is of a conventional construction and can be purchased from industrial supply houses and some bearing supply stores.

Continuing with the discussion of the operation, it can be seen that a rotation of the crank **82**, which is fixedly attached to the main drive gear shaft **90**, effects a similar rotation of the primary air timing valve cam **96**. In that the cam surface **106** is in operable engagement with the cam follower **98**, a reciprocable movement is translated therefrom to the spool shaft **100** thereby to cause the positioning of spool valves contained within the air timing valve **60** so as to control the exhaust and pressurization functions of the conduits **70**, **72**. As a part of this controlled operation, the exhaust air being delivered to the air timing valve **60** by either of the conduits **70**, **72** is directed outwardly therefrom through one or the other of the conduits **102**, **104** and into the pressure equalization transfer-midstroke/venting-pumped pressure transfer manifold **124**, either to be directed to the atmosphere through the pig value **110** or to the low pressure compressed air tank **26**.

At this point of discussion, it should be pointed out that the transfer of air from the high pressure compressed air tank **44** to the low pressure compressed air tank **26** is governed by basic fluid laws. In this regard, it can be seen that if the low pressure compressed air tank **26** contained air at a pressure of 10 PSI and the high pressure compressed air tank **44** contained air at 200 PSI, a pressure differential of 190 PSI would exist. As such, exhaust air at 200 PSI supplied from the actuating cylinder **28** through conduits and the air timing valve **60** will flow through the one-way check valve **126** into the low pressure compressed air tank. As this direct method of air transfer continues, it can be appreciated that when the pressure reaches say 100 PSI within the low pressure compressed air tank **26**, it is no longer possible for the actuating cylinder **28** to deliver full force to the ball joint **80** because there now exists a pressure of two hundred PSI on one side of the piston **76** and 100 PSI on the other side of the piston, therefore robbing the actuating cylinder of half of its power potential. As such then, the back pressure as defined by the 100 PSI pressure contained in the low pressure compressed air tank **26** begins to result in lost power to the vehicle. However, this problem is overcome by the pneumatic drive system of the present invention by a realization of the fact that once an actuating cylinder reaches a certain speed of actuation while doing work (not running free with no load), a point of non-productivity is reached at which the increase of air pressure will not increase the power or speed generated by the actuating cylinder. This phenomenon is due to the fact that increasing pressure to a cylinder also increases the volume in cubic inches of air being forced into the cylinder, as well as the volume of the air exhausting from it. As such, a point is reached where an actuating cylinder just cannot vent and port this much air volume.

Continuing with the operation discussion, exhaust air flows from the air timing value **60** into the transfer manifold **124** toward the low pressure compressed air tank **26** thereby providing a pressure equalization in the manner above-described. This pressure equalization takes place during the first two inches of stroke (push or pull) of the actuating cylinder **28** after reaching a dead center position. The pig valve **110** is closed during this portion of the actuating cylinder **28** stroke so that the exhaust air has no other place to go during pressure equalization except into the low pressure compressed air tank **26**. Once the flowing air passes the check valve **126**, it is isolated from the actuating cylinder **28** and cannot return.

A midstroke venting is then provided and consists of a venting of a small portion of the exhaust air remaining inside the actuating cylinder **28** and in the manifold **124** at the beginning and during the center four inches or center half of both the push and pull strokes. An actuating cylinder is capable of delivering equal force at its connecting rod's point of connection with a crank pin during the entire length of a stroke; however, force and torque must be viewed separately. In this respect, it is to be understood that force delivered to a crank pin that is on dead center is useless in producing torque. For example, 1,000 pounds of force delivered to a crank pin on dead center will produce no torque, but when the crank pin has rotated to a point two inches to either side of an imaginary line between the center lines of a pivot pin and the crankshaft, 2,000 inch pounds of torque are produced. When the crank pin is four inches on either side of this line, a torque of 4,000 inch pounds is produced. This midstroke four inches of cylinder stroke is the portion capable of providing the most power to the wheels of a car. As such, midstroke venting of some exhaust air to the atmosphere to relieve back pressure during this critical portion of each power stroke is undertaken. Specifically, the pig valve **110** opens at selected times to vent the exhaust air to the atmosphere, while the check valve **126** prevents the air in the low pressure compressed air tank **26** from entering the manifold **124** where it would also be vented outwardly through the pig valve.

During the last two inches of each stroke (push and pull), the pig valve **110** will be closed. The actuating cylinder **28** then acts as a piston pump upon the remaining exhaust air inside the cylinder **74** and pumps this air through the manifold **124** into the low pressure compressed air tank **26**. This pumping action does not diminish the torque at the crankshaft or main drive gear shaft **90**, since the sheer leverage available to drive the actuating cylinder to pump air to the low pressure compressed air tank **26** during this last two inches of stroke is many times more than is required for the task. Also, there is regulated air pressure on the power stroke side of the piston **76** during this pumping action. As is apparent from the schematic, the pig valve **110** is timed to operate through the provision of a pig valve actuating cam surface **108** provided on the primary air timing valve cam **96**. In this respect, the surface **108** engages the follower **120** so as to rotate the bell crank **116** within the bearing **118**, thereby causing a movement of the lever **114** against the pig valve lever **112** so as to vent the same to the atmosphere. The pig valve **110** typically should be a high pressure pig drinking valve which has its flow metering orifice drilled out as large as possible so as to maximize air flow therethrough. A two-way spool valve (cam operated) can be utilized to operate just as effectively as the pig valve **110**. In other words, a valve similar to the air timing valve **60** might be utilized except only a two-way valve would be required.

The secondary double-acting actuating cylinder **24** is next in line to use the same air already used in the actuating cylinder **28**, and as illustrated in FIG. **4**, the actuating cylinder **24** is in its midstroke position wherein crank pin or ball joint **150** is at a 90° or maximum torque position compared to actuating cylinder **28** located at a dead center stroke position. Effectively, an analogous operation is performed whereby compressed air contained in the low pressure compressed tank **26** is utilized to operate a second double-acting actuating cylinder **24** in the same manner as aforedescribed. In this respect, the compressed air contained in the low pressure compressed air tank **26** is directed through a conduit **128** to a secondary air timing valve **30** for use in operating the secondary double-acting actuating cylinder **24**. In the event that too much air pressure is delivered to the air timing valve **30**, a pressure relief valve **132** will vent the excess air pressure to the atmosphere. A selective delivering of the pressurized air to the actuating cylinder **24** is effected through the use of a secondary air timing valve cam **36** fixedly attached to the drive shaft **90** and being rotatable therewith, such secondary cam having a cam surface **166** operably engaged with a cam follower **34**. The cam follower **34** is fixedly attached to the spool shaft **32** of the secondary air timing valve **30** and effects a reciprocation of the shaft within the timing valve so as to selectively direct air to or from spaces **156, 158** contained within the actuating cylinder **24**. As such, a secondary driving force is imparted through the crank **154** to the crankshaft **90**, such secondary driving force being in conjunction with a primary driving force provided through crank **82**, thereby effecting a rotatable movement of the main drive gear **22**. The main drive gear **22** is drivingly meshed with the axle gear **52** so as to thereby impart a driving force to the drive axle **46** and the drive wheels **14** associated therewith. As such, the basic operation of the pneumatic system illustrated in FIG. **4** has been described.

FIGS. **5-8** illustrate constructional details relating to the proper positioning and attachment of several of the described parts. In this connection, FIG. **5** illustrates the secondary air timing valve **30** and the conduits **134, 136** associated therewith which communicates with the secondary actuating cylinder **24**. Further, the exhaust conduits **138, 140** are shown operably connected to the air timing valve **30**. FIG. **5** also clearly illustrates the shape of the secondary air timing valve cam **36** which has a cam surface **166** engageable with the cam follower **34**. In that the spool shaft **32** is spring biased in a direction towards the main drive gear shaft **90**, it can be appreciated that the cam follower **34** will at all times be in engagement with the cam **36** and depending upon the positioning of the cam, the shaft **32** will be caused to reciprocate within the air timing valve **30** so as to effect the desired exhaust or pressurization of the respective chambers **156, 158** contained within the actuating cylinder **24**. Further illustrated in this figure is the use of a bearing supports **172, 174** through which the spool shaft **32** reciprocally moves, while a sleeve **176** may be provided on the shaft to limit the movement thereof between the bearing supports. Also to be understood with reference to this figure is the fact that a rotatable movement of the cam **36** results in a pivotal movement of the actuating cylinder **24** about the pivotal connection **162**. This is true since the connecting rod **152** is rotatably attached to the crank pin **150** and must follow the arcuate movement thereof which results in an oscillatory movement of the actuating cylinder **24**. Lastly, the manifold conduit **128** is shown operably connected to the air timing valve **30**.

FIG. 6 illustrates some of the structural connection details of the primary actuating cylinder **28** which is pivotable about connection point **160**. In this connection, the primary air timing valve cam **96** is shown and includes a cutaway portion designed to more effectively illustrate the pig valve operating cam surface **108**. In this regard, the pig valve **110** is clearly illustrated as including a pig valve lever **112**, the displacement of which in a sidewise direction will cause a venting of the pig valve to the atmosphere, such lever being sidewise moveable through the action of the abutting lever **114**. Abutting lever **114** effectively is an integral part of the bell crank **116** rotatably mounted within the bearing **118**. As can be clearly ascertained by reference to this figure, the bell crank cam follower **120** is engageable with either of the two pig valve operating cam surfaces **108** so as to effect a desired rotation of the bell crank **116** thereby to cause the abutting lever **114** to displace the pig valve lever **112**. Also illustrated with respect to this figure is the cam follower **98** which serves to operate the air timing valve **60**, and thus the air supply conduits **70**, **72**.

FIG. 7 is a top plan view further illustrating a possible structural layout of the parts above-described. In this connection, the main drive gear **22** is shown centrally disposed between the primary actuating cylinder **28** and the secondary actuating cylinder **24**. With respect to this possible layout, it can be seen that the primary actuating cylinder **28** is connected by means of connecting rod **78** to the crank **82** while the secondary actuating cylinder **24** is connected by means of connecting rod **152** to crank **154**. Also illustrated in this figure is the fact that the crank **154** and the cam **36** might be of a combined construction, i.e., they might be directly attached to each other. This, of course, leads to the conclusion that the crank **154** and cam **36** could be of an integral construction, thus obviating the need for connection means such as bolts **178** therebetween. Similarly, the cam **96** might be integrally constructed with the crank **82**, although a different layout might be required so as to permit a proper funtioning of the bell crank **116** with respect to its engagement with the cam surface **108**. While FIG. **5** illustrates the use of bearing supports **172**, **174** in conjunction with the spool shaft **32** associated with the air timing valve **30**, this figure illustrates that similar bearing supports **180**, **182** might be utilized to support the spool shaft **100** associated with the air timing valve **60**. Similarly, a sleeve **184** might be provided on the spool shaft **100** to limit the movement thereof between the bearing supports **180**, **182**. Main drive gear **22** is further illustrated in this view as being fixedly attached to the drive shaft **90** by means of a flange **186** which is an integral part of the drive shaft and which is connectible to the main drive gear through the use of some connection means, such as bolts **188**. Accordingly, the drive gear **22** may be easily removed from the shaft **90** and replaced thereby with drive gears of different ratios or with a duplicate drive gear if desired.

FIG. **8** has been provided solely to illustrate the driving engagement of the main drive gear **22** with the axle gear **52** so as to effect a rotation of the axle shaft **46**. As illustrated, the axle gear **52** is separably attached to the drive axle **46** by means of a key **190** which serves to frictionally, lockingly engage the axle gear to the drive axle. Further, this figure serves to illustrate the fact that regardless of the size of the main drive gear **22** in relation to the axle gear **52**, the gear teeth on both can be appropriately designed to effect a proper meshing therebetween.

It is to be understood that the preferred embodiment of the present invention as illustrated in FIGS. **1** through **8** is complete to the extent of illustrating the operation of the pneumatic system designed for propelling the air vehicle **10**, as well as to illustrate one structural configuration whereby the parts might be positioned relative to each other in an operable manner. However, some discussion must also be provided with respect to specific design features not illustrated in the figures provided herewith. While much leeway is available in designing the air-driven vehicle **10**. the preferred embodiment will be herein described with respect to a particular design to thereby facilitate a better understanding of the pneumatic system comprising the present invention. Specifically, it is desirable to start with a gear ratio of 270 teeth to 24 teeth, i.e., the main drive gear **22** should have 270 individual teeth while the axle drive gear **52** should have **24** teeth for engagement therewith. Ideally, it is desirable also to use 24" diameter tires to facilitate an easy calculation of the distance moved by the air-driven vehicle **10** down the road, and if 24" diameter tires are not utilized, it is desirable to add to or substract from the number of teeth on the axle drive gear **52** so as to maintain proper distance calculations. The preferred embodiment also utilizes a 2½" bore, 8" stroke, primary actuating cylinder **28**, along with a 4" crank throw associated with the crank **82**. Secondary actuating cylinder **24** is lager in diameter, i.e., has a 4" bore, but also utilizes an 8" stroke.

The maximum air pressure provided to the primary actuating cylinder **28** is 250 PSI, while the low pressure compressed air tank **26** would carry a maximum pressure of 85 PSI, thus giving the secondary actuating cylinder **24** an operating pressure of approximately 80 PSI due to pressure drop within the system. The larger bore of the secondary actuating cylinder **24** enables it to deliver a force at the crank **154** which is nearly equal to the force provided by the primary actuating cylinder **28**. As such, the secondary actuating cylinder **24** effectively doubles the power of the pneumatic engine without using any additional air to do so. A two-cylinder car can be expected to obtain a little more than twice the speed obtained on one cylinder. A three cylinder car could then be expected to obtain three times the speed of a single cylinder car. Similarly, a four cylinder car can be expected to obtain about nine miles per hour less than four times the speed of a single cylinder car. On the above figures for a two, three or four cylinder car, it should be noted that a primary actuating cylinder pressure of 250 PSI and all other factors such as gear ratio and tire diameter are the same. Further, a car weight increase of 50 pounds for each additional actuating cylinder can be expected. For example, a four actuating cylinder car would weigh approximately 150 pounds more than a single actuating cylinder car due to the weight of the actuating cylinders, the additional low pressure compressed air tanks **26**, and their related hoses and valves. As such, an increase in power and speed is easily obtained without using any additional air per mile down a road.

While a five or six cylinder pneumatic engine could easily be built, no speed or power figures are available. However, a six cylinder engine could be a radial engine with one timing cam and one pig valve cam. The first cylinder migh possibly be a 2" bore rated at 500 PSI with 450 PSI used for a maximum pressure. The six cylinder could then possibly be a 6" bore with other cylinder sizes used between the first and sixth actuating cylinders. A radial engine is envisionable wherein all cylinder rod ends would be connected to one common crank pin having a 4" crank throw. Only one timing cam and one pig valve cam would be required. On a three cylinder engine, the primary cylinder pig valve could port air during its stroke to a lower pressure compressed air tank that supplies air to a third actuating cylinder instead of venting this air to the atmosphere, while the number two cylinder pig valve would continue to vent to the atmosphere. On a four cylinder engine, the primary cylinder pig valve would port to the number three cylinder pressure tank, while the number two cylinder pig valve would port to the number four cylinder pressure tank and the number three cylinder pig valve would then vent to the atmosphere.

Because of increased power expected with respect to three and four cylinder cars, gear ratio changes to effect even better air mileage could be made. For example, a **21** tooth axle drive gear could be used on a three cylinder car while a **19** tooth axle drive gear could be used on a four cylinder car. Less drive teeth than this would be inefficient in the transmission of power. For the purposes of town driving, there should be provided at least 1500 cubic feet of air storage capacity so as to attain a respectable distance before exhaustion of the air supply. 1500 cubic feet of air could be four "T" sized compressed air tanks plus a scuba tank. These tanks can be obtained in any practical length.

The foregoing discussion has related somewhat to specific dimensional relationships between respective parts as well as to some discussion relating to desired operating pressures, etc. However, optimum dimensional relationships for the parts of the invention are deemed readily apparent and obvious to one skilled in the art, and all equivalent relationships to those illustrated in the drawings and described in the specification are intended to be encompassed by the invention, subject only to limitations specifically appearing in the claims. As such, the foregoing is considered as illustrative only of the principles of the invention. Further, since numerous modifications and changes will readily occur to those skilled in the art, it is not desired to limit the invention to the exact construction and operation shown and described, and accordingly, all suitable modifications and equivalents may be resorted to, falling within the scope of the invention.

What is claimed as new is as follows:

1. In a fluid power operated motor system, including at least one pair of double-acting piston devices respectively having piston elements separating opposed pressure chambers, and a storage source of pressurized fluid, the improvement comprising first valve means operatively connecting said storage source to one of the piston devices for reciprocation of the piston element thereof in response to alternate pressurization and exhaust of said opposed chambers, pressure accumulating means connected to the first valve means for receiving the fluid exhausted from one of the opposed chambers of said one of the piston devices, second valve means operatively connecting said pressure accumulating means to the other of the piston devices independently of the storage source for reciprocation of the piston element thereof in out-of-phase relation to the piston element of said one of the piston devices, mechanical power transmitting means drivingly interconnected with the piston elements in said out-of-phase relationship, valve operating means driven by the power transmitting means for limiting transfer of fluid exhausted from said one of the piston devices to the pressure accumulating means during spaced intervals of time, and vent means actuated by the valve operating means for venting the fluid exhausted between said spaced intervals of time.

2. The combination of claim **1** wherein said storage source is a rechargeable, compressed air tank.

3. The combination of claim **1** wherein said power transmitting means includes a vehicle propelling drive train.

4. In a fluid power operated motor system, including at least one pair of double-acting piston devices respectively having piston elements and a storage source of pressurized fluid, the improvement comprising, pressure accumulating means operatively connected between said piston devices for transfer of fluid exhausted from one of the piston devices to the other of the piston devices, valve means connected to said piston devices for pressurization of said one of the piston devices and limiting said transfer of fluid exhausted therefrom to spaced intervals of time during which the storage source and the pressure accumulating means are substantially equalized in pressure, and vent means for venting the fluid exhausted from said one of the piston devices between said spaced intervals of time.

5. The improvement as defined in claim **4** including mechanical power transmitting means operatively connected to the piston elements of the piston devices in 90° out-of-phase relationship to each other for actuation of the valve means and the vent means in response to movement of said piston elements through a predetermined stroke.

* * * * *

SPIRIT OF JOPLIN AIR CAR
ENGINE CONSTRUCTION

Transcription of 3 hours of audiotape by the inventor, Terry Miller
6 tape sides of ½ hour each
recorded in about 1996
Terry Miller is now deceased

(side 1)

Our group in Joplin, Missouri is dedicated to running clean cars on compressed kinetic energy in the form of clean air, and we've used this kinetic air energy to power a fleet of cars.

If you're looking at drawing #3, I'm gonna go ahead and explain the different nomenclature and how these engines are put together. This engine is very, very simple in construction. People sometimes think it's complicated because they see the parts hanging out. Yes, the parts are hanging out, but the main thing is that there's very few other parts inside. This is very easy to work on.

The most prominent feature that catches your eye right off the bat is the large gear. It's a Martin 140-tooth gear, it's 8 diametral pitch teeth, and a 14-1/2° pitch angle on the teeth, if you'll notice on that big gear, it is not a flywheel because it doesn't turn fast enough to give you any flywheel action. You'll notice right down below the gear if you just figure if the gear was all wet with water and water was dripping off the gear, at the bottom of the gear where the water might drip off the gear, the round circle you see there is an oil-lite bushing. That oil-lite bushing is in a tube and pressed into the tube, and 2 of those bushings go all the way through the motor frame. Now that motor frame is 1/8" welded square steel tubing, 3" is the measurement, it's 3" square tubing. Anyway that oil-lite bushing is in a steel tube which is welded in the motor frame, and that oil-lite bushing is in a position to hold the gear and a 1" shaft which ties to the axle of the car.

Now the other fitting that you see sticking out to the left is one of several extra fittings that we welded onto the motor frame for instrumentation and different uses. And the bead welded at the bottom of the motor frame, on the picture roughly an inch and a half below the circle denoting the bronze bushing, you see a bead running at a 45° angle up and down about 2 inches long, this is a steel plate, 3/16" steel plate, little bigger than 1/8", which is welded to the bottom and it forms the end of the tank. The tank is in the shape of a T, if you'll trace on upwards now you can see on the lower left hand corner of the picture and the upper right hand corner, from one position to the other is another section of this 3" square tubing. Those 2 welded together with plates on each end make up an air tank to hold some of the air that's used in the engine.

Now probably the next most prominent feature after noticing the 140-tooth gear—which is by the way a cast iron gear—is the two cylinders. Now by cylinders we mean the part that at the lower left hand portion of the picture there seems to be a bolt attachment, a pivot point there, and those pivot points allow these cylinder to pivot from this end, so they're a rear pivot cylinder. And each of these cylinders, the one says "Bimba" on it, upside-down in the picture, who is the manufacturer and supplier of the cylinders that we use. Two cylinders, the lower one in the picture is a 3" bore cylinder meaning the piston in the cylinder in the inner bore is 3" in diameter, and the other one that appears to be gray-painted, and it is painted gray, is a 4" bore cylinder, and it's a double wall cylinder, and it's quite a bit larger than the 3" cylinder. Each of these two cylinders has a piston and a rod.

The piston is inside and attached to the piston is the rod, which you see coming out of the right hand side of the cylinders, and in the picture the stainless steel cylinder, the lower one, the 3" bore cylinder, the rod on it is at the center position, as far as being fully, we would say that would be at the top dead center of the stroke, that's what we call it, "top dead center," that rod is almost fully extended, and on the end of the cylinder rod is a standard rod end. If you'll look at the other cylinder, which has a piston inside and a rod, and you'll notice that the rod is larger, because that cylinder in the other uses could be expected to do more work and to have more force that it can put out because it is bigger, and you'll notice that there's a rod end on that shaft too. They're standard rod ends, available over-the-counter anywhere in the world.

Attached to the rod end coming up vertical about a 45° slant, is a piece of ½" steel tubing with a threaded nut welded on it, it's a 5/16" nut, and the combination of those three metallic pieces, the rod end, the short length of ½" welded steel tubing, and the mechanical nut, which has been welded on the end, and then the thread has been polished out a little bit to allow for sliding, we call that piece that's been welded onto the rod end, we call it the striker, and it strikes the set collars that are on each shaft as it moves up and down, we'll explain that later, but because it strikes the collar it comes up with its nomenclature as the striker, and we don't yet have a name for the rod end/striker combination, so we don't talk about the rod end/striker, we talk about the rod end and we talk about the striker.

Any engine that does cranking work, whether it's a steam engine, or this particular air engine, or a car engine, has to have a crank and also a crank pin to tie the end of the rod to so the engine can reciprocate and turn the reciprocating action into rotary action. In this case, if you'll refer back to the large 140-tooth cast iron gear, the rod end there has a code 9, high tensile strength bolt going through it, and the spoke on the gear has been threaded, drilled and tapped to receive the bolt. You'll notice that the opposite spoke on the other end also has a hole, both spokes were drilled and tapped and threaded, so if one ever messed up, the threads were stripped or wore out in any way, you could go ahead and change the crank pin which is your code 9 bolt, you could unscrew the bolt and put it down into the other spoke, and you'd have an extra crank pin and it wouldn't effect the operation of the engine any, you'd still function in a manner which is easily recognized right now.

We mentioned that the rod end was at the top dead center. If you'll look at the rod end on the upper gray-painted 4" larger double-acting cylinder, you'll notice that the rod end there is in a position which is neither bottom dead center, which would be fully withdrawn into the cylinder, or top dead center, as the 3" steel cylinder with the word "Bimba" on it, it is actually in the mid-stroke position where it is able to deliver the most force when there's air pressure in that 4" bore cylinder, that crank is what we call "out." Since we designed these engines and build these engines and they employ our sequential re-use of air to obtain energy efficiency, we can call the parts anything we want to, and where they're at we can say they're at anywhere we want them to be, so with the cylinder fully extended out, the rod all the way out, that's top dead center, that's all the way back, it brings the gear into a position in relation to the cylinder and the pivot pin at the back, which we call bottom dead center, and the position that the crank is on the 4" bore cylinder, we're able to deliver its maximum force, or 90° out, we call that being "out." The crank is "out," the crank is at top dead center, the crank is at bottom dead center. Now for every rotation of the 140-tooth gear, there'll be a position where the crank is at top dead center, there'll be only one position, there'll only be one position where the crank pin will be at bottom dead center, and in these positions, the cylinder is unable to produce any meaningful torque to apply it to the rotation principle of the engine, it would be able to supply force, but no torque, because you're at top dead center and at bottom dead center, and there's only one of each position. However the crank on the 4" bore cylinder, and the crank on the 3" bore cylinder, as it rotates, the crank is in the position we call "out" twice for each rotation of the gear, so when the crank on that 4" bore cylinder is pointing upward and to the left at a 45° angle, when it's down opposite, those two positions would be called for by saying that the crank is "out." So this engine in one rotation carries on through to the cranks being out four times, the crank pins being at top dead center or the cranks being at top dead center twice, and at bottom dead center twice, because we have two double-acting cylinders.

What we want to do now is go ahead and get back to the steel square tubing, it's 3" square tubing 1/8" thick that welds up to make the motor frame of the car. Now, not only does this provide an air tank for the re-use of air from one engine to the other and from one cylinder to the other, and also provides a means for a motor frame, it also, due to the fact that the rear pivot pin bolts, which are also heat-treated strong bolts, those are welded into the motor frame and they provide a very strong support for the rear pivot bronze oil-lite bushings on the cylinders that provide the rear pivot pin for these two to pivot around. Also where the crank for #4 cylinder is, and the crank for the 3" bore cylinder goes through, this provides your crankshaft bearing retaining structure to hold the crankshaft for the engine. And the bronze bushing that we mentioned pictured just below the large gear, that shows clearly that the motor frame also serves as a support for the driveshaft gear. Then at the upper right-hand part of the picture, the plate appears to be welded on not square with the tubing, and that's so that the engine can be positioned into the car. That steel plate bolts to the firewall of the car, the metal area separating the driving compartment from the engine compartment. So this engine is real easy to remove from the car, there's one bolt back by the pivot pin bolts that extends downward to a shock mount, that bolts to the cross-member of the car, and the other mounting point for the engine is ¼" bolts, three of them, which go into the firewall of the car. You disconnect your driveshaft, slide the set collar back, pull the nut off the bolt at the bottom of the engine at the front of the car where it goes into the carry-through, and you unbolt the three bolts that hold the front of the engine to the firewall, and you have to disconnect your air hose coming out of the #4 cylinder where it might be going into your tailpipe, and you disconnect the air hose going into the cylinder, and you can lift this whole engine out of the car in just about a minute very easily and put it back in just as quickly.

The other items that have yet to be mentioned are the washers that you see pictured most clearly on the rod end on the the 3" bore cylinder that is at what position? Top dead center. Those washers are various sizes and also they're bronze bushings, and they're made different sizes on purpose so that the bolt can be tightened up securely and torqued down into the spoke of the gear serving as your crank pin, but also the washers are so designed that the rod end and the bearing surface on the rod end is allowed to rotate in the direction of when the 140-tooth gear turns, but also the washers take up the space between the ball joint as you might say—I've always called rod ends "ball joints" but they're called rod ends, there's a space there between what would normally be the head of the bolt and the outer race of the ball joint or the rod end, now if there weren't any washers there, then the striker which is welded to the rod end, would be allowed to swing over and hit the gear with nothing to stop that rod end from slapping to the left or the right, or in other words, if the striker moves toward you away from the picture or back towards the motor frame, it would rotate far enough to get tangled up in the main gear or hit the motor frame or to misalign the rod that it supposed to actuate again. So we use different size washers and different size oil-lite bushings so the nut can be tightened up tight, and all the strikers, which are welded to the rod ends, when the rod end wants to slap a little bit back and forth, I would imagine that on one of our cars if you took ahold of the nut that's been welded to the ½" square welded steel tubing to make up the striker and if you pulled that left and right in the vehicle, not forward and back because it won't move that way, but if you moved it left and right your total travel would probably be somewhere in the neighborhood of ½" maximum, which is perfectly desirable and works out real good.

OK, now let's proceed on up. We're bypassing for just a little bit the spool valve and the operation of the spool valve, cause we haven't even gotten into the mechanical operation yet let's go ahead and cover the mechanical things that are important, but the gray part that looks like it has all the (?) in the end of the spool valve, all the ports and all, we're gonna bypass that for now and discuss this rod, you'll notice each one of the strikers has a rod going through it, now this rod also affixes to the timing of the spool valve to move the spool within the valve, but let's just say we're gonna push and pull on this rod, but what is gonna cause this to be able to do the pushing and the pulling. So here's the way we're gonna do it. As the 140-tooth gear rotates, and the crank pin goes from top center around to the out position and around to bottom dead center and on back up to the out position, on through the out position and back out and through the top dead center position and back into the out position, it will be obvious that as the rod end moves to the left and the right in the picture, at a 45° angle in the picture, and the rod end will be all the way down close to the double-acting cylinder, or as far away from it as it can get, if that rod does not move, and it has nothing acting on it to make it move, and the slack inside that striker is enough to allow it to strike on the rod, then that is exactly what will happen.

As the 140-tooth crankshaft gear turns, as the cylinder goes to push to pull acted upon by air, the piston's drawing the rod all the way out and all the way back in and the rod end will move back and forth and because the striker is welded to the rod end, it will come back and forth, and it will slide along this rod. Now the rod in this particular engine is ¼" diameter steel cab-plated rod, and the two set collars that look like set collars and that's exactly what they are, in the striker that we're looking at on the 3" bore cylinder, the one that's fixed to the rod end, that has the crank pin bolt going into the 140-tooth gear, that striker right now is probably maybe ¼" from hitting the set collar, and as that 140-tooth gear finishes its rotation clockwise like in this picture, that striker will hit that set collar and when it goes on around in a circular, completing a little bit of circular motion, it will hit the set collar and will pull the rod to the right, or up into the upper right-hand corner of the picture. Now when the crankshaft gear turns 180° and comes on back, the striker, being attached to the rod end, will come all the way back and it will hit the opposite set collar on shaft, and it will cause the shaft to move in the opposite direction, so every rotation of the crankshaft gear, and also every rotation of the crank, and every rotation of the crank pin, and every rotation of the opposite crank, which is only a crank, there's no crankshaft gear there, it has to be the opposite component of the crankshaft gear, we only need one crankshaft gear so on the opposite side all we need is a crank.

But for every rotation you will get two mechanical clicks as the engine rolls around one revolution and the striker hits the set collar and it'll rotate around 180° again and hit the other set collar, and in rotation as this engine rotates, if it rotates slowly and you can pick this up on a recording or something, every rotation will sound something like this (click, click, click, click), and another rotation will sound like (click, click, click, click), because the two cylinders are 90° out from each other, when one cylinder is at top or bottom dead center, and the other crank has to be where? It has to be out or out, one or the other. Now you won't hear timing clicks on these engines where the spacing isn't right, you won't hear anything like that all the clicks you'll hear will be right together. If you count these clicks and divide by four, you'll know how fast the engine is running. If you hear you clicks close together, you'll know the engine is running reasonably fast. Because the rpm at which this engine runs most efficiently appears to be from our experimenting and our working, you'll get the most energy efficiency from this engine at roughly 40 revolutions per minute, which is very, very slow.

All right, we'll get back to the strikers now. The rods are attached to the spool on the spool valve, and we'll basically review this a little bit, in that each spool valve, which covers the venting and the porting of the air, that is attached to each double-acting cylinder, they go in pairs, every double-acting cylinder needs a valve to vent and port the air to make the cylinder push and pull, so every double-acting cylinder will have a spool valve attached to it, they will all be rear pivot-mounted cylinders they'll all be double-acting cylinders, they'll all have a provision up front to attach a plate or some mechanical steel device to hold the spool valve, and the cylinder has a provision to be mounted at the front, and we take advantage of the cylinder's provisions to be mounted at the front, in order to have a place to attach the spool valve. OK, the 4" bore cylinder has four bolts up there that hold the cylinder together, and those four bolt holes also provide provisions for what in the Bimba catalog is called a plate mounting or a stationary bench mount type bracket if you will, it's available, where the cylinder can be bolted securely at the rear and the front, and where you wouldn't be using the pivot portion at the back. The 4" bore cylinder has a pivot bearing that bolts on at the back, and instead of a mounting a mounting plate at the front, we took a mounting plate and trimmed it to a smaller size, and instead of using it to mount the cylinders with, we took a piece of 3/16" X an appropriate length and width to mount the spool valve to, and we welded the steel plate to this mounting bracket, bolted the mounting bracket to the cylinder after drilling the holes to attach to the spool valve with 3/16" bolts. The spool valve that you see on this 4" bore cylinder is bolted on with four bolts and the bolts attach it to the steel plate, the steel plate is welded to the modified mounting bracket in the front, which provides a very secure position for the spool valve.

(side 2)

….timing arrangement for that spool valve. Before we get into the operation of the spool valve, let's get into the operation of the 3" bore cylinder, which has Bimba on the side of it on a decal upside-down, let's look at the cylinder there, if you'll look you'll see the outline of a large hex standard machine nut, and this particular cylinder where you can just stick it through a piece of plate steel, or stick it through an angle iron with a hole in it, and run the jam nut down against it, and when you purchase this cylinder you can actually purchase a front mount bracket with it, and modify the front mount bracket to hold the steel plate to weld to the mounting bracket to bolt the spool valve to by drilling holes in the plate and using bolts to bolt it to. The difference in the two is that this particular mounting bracket is a large threaded portion on the end of the cylinder, and the mounting bracket fits over that large threaded portion and that jam nut tightens it up. You have to be careful in this particular installation, in that when you tighten the jam nut, you need to hold the cylinder securely, and you need to have the spool valve positioned properly on the cylinder, so the air ports are out at approximately 90° so the cylinder can pivot up and down and you can still maintain your hose connections the way you want them, but you have to be careful that you don't tighten it up enough that the aluminum portion on the cylinder is not supported in a way that it might cause it to rotate within the stainless steel tubing. That's about the only way I know you could damage this cylinder tightening the nut is if you don't take the proper procedure in holding it when you tighten the nut.

So other cylinders by other manufacturers might have other types of mounting brackets at the front, we call the front of the cylinder, the portion of the cylinder where the rod comes out of, and we call the back of the cylinder where you either have a rear pivot point built into the cylinder, which is the lower left hand portion of this picture, you'll either have, in the case of the 3" bore cylinder, the rear end of this cylinder is aluminum, you can see the ring where it is swaged approximately an inch in at the front and the back of the cylinder, we call this the back of the cylinder, and we call it the rear pivot point. In the 4" bore cylinder, the rear pivot bracket bolts onto it, they're interchangeable with other, so there's possibly, I know Bimba, all 4" bore cylinder have different mounting provisions and different accessories. But this is a rear pivot bracket which is available from the manufacturer and other manufacturers, we're very partial to Bimba.

Now we get to the point here where we've pretty well covered the nomenclature, we're gonna go through it one more time. Each cylinder has a shaft, technically I believe they're called a rod. We call them shaft or rod sometimes, let's stick with rod. Then on the end of each rod is screwed a standard rod end, some people call them alignaballs because a lot of people buy the Alignaball brand of rod end, we're not partial to any rod end manufacturer because most of your manufacturers make rod ends and they all seem to be very useful. The cylinder walls or the curved tubing that makes up the tubing varies from manufacturer to manufacturer, the 3" bore cylinder in this case is stainless steel, I believe the cylinder inside the 4" bore is aluminum, this is a double wall cylinder that bolts together, they do the job very well.

The piston inside the cylinder has air seals, and these cylinders are called double-acting, because if you put air into the port at the end of the cylinder it will blow on the piston with kinetic energy and force that piston to the back of the cylinder, and since that piston is attached to the rod, it will bring the rod back with it and it will bring the cylinder back to the position in the engine that we call bottom dead center, then if we put air into a port between the back of the cylinder and the piston, we put air in a port and pressurize it there, then that will go ahead and force the piston toward the front of the cylinder, force the rod in the cylinder to extend outward, and rotate and drive the rod clear on out to the top dead center position, and I'll remind you at this time that on the way to the top dead center position it will have the crank out, as in the case in this picture, the 4" bore cylinder, the crank attached to the rod on that 4" bore cylinder is in the out position and the crankpin and crank for the 3" bore cylinder, the stainless steel Bimba cylinder, is in the top dead center position.

So each of the cylinders, the stainless steel cylinder, the 3" bore cylinder at the lower part of the picture, it also has a piston, now let's figure out where the pistons would be. In the stainless steel cylinder at the bottom of the drawing, the rod is all the way out, and we're at top dead center with the rod end and the crankpin bolt in the crankshaft gear, so the piston must be awfully close to the end of the cylinder. You see the two bolts that bolt the spool valve down to the plate, that's attached to the front mount bracket, those bolts are regular AN3 hex head bolts, and right about in there would be where the nut goes on that bolt would be where you would expect to find the piston. Now, if we look at the 4" bore cylinder and the crank is out, you would expect if you had x-ray vision and you could look into that cylinder, you could expect to find that piston halfway between the rear pivot point on the cylinder and the front of the cylinder, the front is what we call the portion where the shaft or cylinder rod comes out of the cylinder. So your piston position within the cylinder and what forces are acting upon the piston depends upon where that particular cylinder's rod end attached to its rod happens to be in the rotation or it happens to be in the clocking of the engine, whether it is out, halfway between out and top dead center, or halfway between out and bottom dead center or measuring from top dead center 10° of rotation, 20° of rotation, 30° degrees of rotation, 40° of rotation, all this will determine where the piston will be in the cylinder. And when we get into the theory of the sequential re-use of air, the position of the piston within the cylinder is very important.

It's also essential in the mechanical makeup of this engine, since it is comprised of two double-acting cylinder, that the cranks not be opposed. In other words, we wouldn't want to have both cranks to be at the center position, one at top dead center and one at bottom dead center at the same time. If we did, let's think about it a minute, if both cranks were out at top dead center at the same time, the engine would still function, if air were put to both the timing valves on the engine. If both the cranks were at bottom dead center at the same time, the engine would still function, but from a mechanical standpoint, and from a sequential re-use of air standpoint, making it work, you would still only have the benefit of one, as far as getting any advantage at that type of operation where both cranks were out, both cranks were at bottom dead center, at top dead center at the same time. You wouldn't get the mechanical advantage that you get with this engine, and you wouldn't be able to get into the sequential re-use of air. So for review, the cranks are 90° from each other. When you find one of the cranks at top or bottom dead center, the opposite crank will always be out.

This engine will run either direction. If the crankshaft gear you're looking at right now is turning clockwise, then the crank will also be turning clockwise as we're viewing it, along with the crankpin on the crankshaft gear. If you stop that engine and by some mechanical means you bleed the air pressure off of it, or if you simply manipulate the timing rod that it goes through the striker manually and manually manipulate the timing, you can reverse the engine. The engine will run forwards or backwards, because the cylinders are that way, the gearing is that way, the car will run forward or backward, and the other gear that goes into the crankshaft gear determines your gear ratio, then if you have a transmission that ties to this crankshaft gear, then you can have several speeds forward and one or two or whatever for reverse.

OK the mounting of the spool valves is unique in that of all the spool valves I know that are available, the Westinghouse Air Brake Valve, or the WABCO valve, which is obtainable from Rexroth International Pneumatics, is one where you can pull the bolts out of the different air segments on the valve, and you can literally clock the different segments of the valve. We're gonna take the time, we're gonna go slowly into this spool valve, and describe what you see in the picture, and then we'll do what we can to explain the function. The valve which we have right now, which shows all the ports at this time, is the spool valve which is located on top of the stainless steel cylinder, the 3" bore cylinder. Those are red plastic cups stuck into the tapped exhaust ports, not necessarily exhaust ports because that changes it, let's clarify the fact. There are five ports in this valve, and the ports all have cups in them when you receive it to keep dust and dirt out of the valve, but when a valve, in the nomenclature of the catalog, when the valve says it has tapped exhaust or tapped ports, they mean you can look for standard pipe thread where you can plumb in your pneumatic fittings and your pneumatic plumbing to get your air in and out of this valve to work the double-acting cylinder either in the push or pull position. If you'll notice the spool valve that's on the 3" bore cylinder on top of the picture, you'll notice that it only shows three ports, and the reason is that the other two ports or on the opposite side of the spool valve.

OK, back to the 3" bore cylinder and the spool valve sitting on top of it. If you'll notice at the rear of the spool valve, which we call the section closest to the rear of the double-acting cylinder, there are what appear to be three hex-head bolts showing, and there also appears to be three to four hex head bolts showing at the front of the spool valve. These are actually nuts, and there's a threaded rod that goes all the way through the spool valve, similar to the rods that go through electric motors, this spool valve bolts together the same way and it can be assembled very easily. You disconnect the four bolts that go through any of these Rexroth Wabco spool valves, and if you just slide the bolts out, even though this one section is bolted to this steel plate, any of these tapped ports can be rotated, there are segments that can be rotated.

So let's figure this out right now, let's go to the back of the spool valve, and we'll find the two bolts that bolt the spool valve down to the plate, that one plastic cup there covers a port, and there's a thin line that you may be able to see in the drawings where these sections bolt together, and there are o-ring seals and cup seals that provide air holding capacity between all these ports. Also the spool that slides back and forth in this valve housing is called a spool because it actually resembles a sewing machine spool. It actually has indentations in it that, as the spool moves left and right, it will allow different ports on this spool valve to be connected pneumatically with each other. OK, if you pull these bolts, any one of these ports that you see on the spool valve, let's take for instance the port at the rear of the spool valve, which is closest to the rear pivot point on the 3" bore cylinder, if you pull the rods on each end, that port can be rotated around to where the port on that cylinder can be lined up with the adjacent one, which is the next one over, then you go on over to the next one that appears to be on top of the spool valve, it is the center of the five. If all the bolts were removed, you could actually rotate it down. Then you can go to the one that's on top of the spool valve, at the front of the spool valve, closest to the crankshaft gear, where the timing rod attaches to it; all five of those ports can be pointing in one direction, or all five of the ports could be pointing up, or they could actually be rotated to point down, and if there wasn't anything above that steel plate, you could cut a hole in the steel plate to plumb your plumbing into that spool valve.

These spool valves are a dream, they're absolutely light to use, because it seems like every engine we put together and everything we do, we decide that we decide that we need to use the plumbing and the hoses in the cylinder a little different, and we'll get into that on another drawing, about the plumbing and the hoses.

Now, at the rear of the spool valve, there's a black, seems like a perfectly square cube, and I believe it's fiberglass-reinforced plastic. That's a detent kit. We use a detent, which is available from Rexroth Pneumatics. The detent kit just simply has an attachment that ties to the spool, which is a long stainless steel rod within the valve housing, with indentations in it which allow for the porting of air from one of these tapped ports to another. But to hold that spool valve in a particular postion, detent kits are available to hold the spool valve, it's subject to vibration, so it won't move on its own if you shake it or jar it. Detent kits are available to hold this spool valve in the center, or just to one end or just to the other end. The detent we use, obviously we use the detent to hold the spool valve where the spool is moved fully forward or fully backward, because in those two positions is where we're controlling the venting and the porting of air, and telling the cylinder whether to push or pull. So these detent kits simply have a spring and a ball, and the ball pushes into a groove on the detent, and the spool valve has this tendency, if you listen with a mike pickup and you move the spool valve back and forth, you can hear the little ball drop down into the detent, click, click, click, click. You can't hear it with the engine running, but if you put a microphone on it and work the rod by hand you can hear it. This detent kit is needed for one reason. Just look at the spool valve and picture a spool in there with detents in it that allows for the porting of air, and then the end of that spool is attached to the timing rod, and the nomenclature and what we call this is the timing rod.

So we have the striker made up of the ½" steel tubing with a nut welded on the end, we have the timing rod which is ¼" cab-plate steel, and then the set collars you can identify real easy, well you can't identify them real easy but they are set collars and there's a set screw adjustment for timing, and once we get the timing set where we want it, which is real easy to do, we'll tack weld it, and this particular method of timing has proven to be very, very reliable. It's a little noisy, and we don't mind that, and actually if you wanted to put a little rubber washer on the timing rod so that the nut on the striker, when it hits the set collar, it will actually be hitting this small rubber washer first, that will probably get your noise down to practically nothing. So as this engine goes around, if it's rotating at say 8, 9, 10 revolutions per minute, you'll hear the striker hit the set collar. Of course at 40 rpm or 50 rpm or 60 rpm, it's faster than you can count it; you could record the clicks and then run your tape player slower to count your rpm, but when you're running faster all we need to do is to count the exhaust, and divide by 2 to get engine rpm, or to have a muffler on one exhaust and no muffler on the other, and then we just count the loudest exhaust noise, and the number of exhausts that you hear in a period of time will give you the rpm.

Now, the spool valves we've explained that the tapped exhaust ports can be clocked in any position, and a real good way to explain that is, at the three ports that you see on the spool valve closest to you on the stainless steel 3" bore cylinder, in the cluster of the three ports, the one in the center on the top of the spool valveis the one that you would supply air pressure to. Then, the two ports that are pointing out sideways from the spool valve, those two ports we would call the pressure ports, and the other two ports which are at the extreme forward and aft portion of the spool valve on top, we call them the exhaust ports, and that's their function. If we take the two threaded ports on the spool valve which are pointing out and not up, on the spool valve, and run a hose from that tapped port down to the inlet port at the front of the cylinder, which you can see it, it shows up black in the picture, then we run a hose from there to there then we run a hose from the other threaded port which is pointing out, to the rear pivot portion of the cylinder where the black hole is that you can see, it's just black, that port is also threaded, so we hook up a hose there and there, we put pressure in the center, so when the spool valve is pulled all the way out, or all the way back, or the spool is moved to the front or the back, the pressure entering that center port will be directed to either one of the other two ports adjacent to it and pointing out. They will never be supplying air to both ports at the same time.

Now, the other two ports on the spool valve are simply used to collect the exhaust from this operation, and we save that exhaust via a manifold which we call manifold 16. It's the pressure equalization transfer, mid-stroke venting, pumped pressure transfer manifold; we'll get into its operation later. But this spool valve, again, if you're ordering one from Rexroth International, is a 4-way spool valve with tapped ports, closed center position, and you can order one with a detent kit, and the plumbing ports on these spool valves are ¼" pipe thread. The 4" bore cylinder is large enough that the hose going into the spool valve mounted on top of it, you can only see three ports because the other two ports are pointing out, and they're on the opposite side of the spool valve from the pressure port that you can see, and those two ports we plumb to the push and the pull of the cylinder—I'm sorry I made a mistake, they're the two ports that you see in the drawing, pointing up; they haven't been clocked yet in this arrangement. We'll pull the bolts out of that spool valve and those two ports will eventually be pointing out so that the hose can go from there, around, make a u-turn and come back into the cylinder, and the exhaust portion will be on that side, and they'll leave and go down and under the car and out the tailpipe, and the pressure port we'll probably rotate up, we'll check it when we see the drawing. So that's the nice thing about these spool valves, you can clock the ports any way you want to. Now the reason the five ports on the spool valve on the 3" bore stainless cylinder at the bottom, the reason you can see all five of those ports is real simple. As this crankshaft gear goes around and the crankpin goes to the out position either at the top or the bottom down there of the picture, if you had any plumbing coming out of the side next to the motor frame, the up and down action of the cylinder would just wipe the plumbing right off, because the motor frame would hit it.

(side 3)

The detent kit which in the drawing is the black square shape portion at the rear of each spool valve is an accessory available from Rexroth Pneumatics to go with their WABCO Westinghouse Air Brake valves. These detent kits are probably one of the best devices in this engine to minimize timing problems. As the striker moves up and down the timing rod, there's a little metal to metal friction there, and we have added a little bit of oil on occasion where the rod was dragging a little bit, and that oil collected dust, and then in cold weather—a lot of times, everybody knows that, like on a racing engine sometimes you can be using 20 weight or 30 weight oil, and if you'll put 10-weight oil in the engine, the engine will wind up faste—what it boils down to is the timing rod has to remain dry, but also you don't want any bumps in the road or anything else telling this spool valve, "I'm gonna make the cylinder push," when the spool valve is telling the cylinder, "Oh no you're gonna pull instead of push," you got problems there. There don't appear to be any gremlins in the timing. It is so simple and so straightforward, and I have yet to be able to figure out a more positive and quicker way of timing unless we were to go to electrical solenoid operated spool valve which we could, but if you had a loose connection, a dirty connection, a broken wire or something, then you'd be out of the timing business. This has proved to be very reliable so far, and you don't oil the push rod because it collects a little dust which causes a drag, and in cold weather too, the dust and the oil combination could cause the spool valve to be pushed into the wrong position. So essentially your push rods remain rods, your detent kits are great, they are available, we have used spool valves without detent kits, but if you're planning on building an engine, the detent kit is not all that expensive, and it will sure make up for a multitude of errors, cause if your timing rod gets a little oil or a little dust on it, the detent kit will hold it in position even on bumpy roads, so it's well worth your time to explore it.

OK, I'm thinking about the things that need to be covered on the particular engine, and we're still on drawing #3, the cylinders can be obtained by contacting Bimba Cylinder Manufacturing Company in Monee, Illinois, they're just out of Chicago up there. The crank that shows in the picture attached to the crankshaft and on the opposite side of the motor frame from the crankshaft gear, is made out of steel, it's approximately ¾ of an inch thick and wide enough to be strong enough, you could put a ruler on these drawings and do a lot of scale up and figuring dimensions on your own. But the thing about the cranks, and the thing about the crankshaft gears is that we have a lot of brute force, when you figure that you have a cylinder capable of putting several hundred pounds of force on a crank, you determine that this crank had better be tied to the crankshaft securely. Now, in our more advanced engineering that we're doing, we have a firm here that's a sponsor, and they helped us early on with our Pneumatic Urban Commuter Club projects, they have machined a crankshaft that goes through the flywheel gear, and the shaft is machined with a head on it, and the head presses in to the crankshaft gear which is machined to accept this head, and also there's a set keyway, and this is all a press fit, so there's just no way in the world that crankshaft can get off of the gear, or the gear separate itself from the crankshaft—from the flywheel gear which serves as a crankshaft.

Now on the 4" bore cylinder—let's get back to the crank that goes onto the crankshaft—that particular crank in this engine was machined to a few thousandths tight fit, and it was pressed onto the crankshaft, and the crankshaft was 1" diameter, but it was pressed through the crank, about ¼" through the crank and then welded around. And we found that you have more holding power if you do not countersink the crank and weld down into the countersunk area, that in some ways only gives you maybe ¾" of the diameter circumference given area of the shaft to hold onto the weld, but if you press the crankshaft through the crank a little bit and weld all the way around then you're extending out on the 1" circumferential area that you get because of the 1" diameter shaft, you get more holding power on the crankshaft. If you want to build an engine with a minimum of machining, you can put one of these engines together and order all the parts and have it all put together in four weeks or less. If you want to use a steel gear for your flywheel gear, you can press the shaft through the steel gear, press fit several thousandths tight fit and weld it, and you can weld your cranks on, and then if you want to disassemble the engine you can take a grinder to your crank to disassemble it, however you can always weld the shaft to the crank and then put the crankshaft gear on, keyway to press fit with a nut to hold it, if you're gonna go to a cast iron gear.

The whole motor frame of this car, and the tubing is welded together. You want to keep the tubing clean inside, wash your tubing with soap and water, and don't have any oil on it at the time when you do the welding, and the fittings that you need for air, the fittings that we use are just simply standard tapered pipe thread couplers cut in two, and the couplers are welded into the motor frames in different places after drilling a hole for air passage, now before you weld the plates on all the ends of all the motor frame, which also serves as the re-use tank, you can clean and blow out any metal particles and oil and debris from the tank, and then weld the plates on the end. Then what we do is fill the whole motor frame, not the whole motor frame, but put about a half a quart of oil in the motor frame and slosh it all around and then pull one of the drain plugs and let the oil drain out, and this coats the inside of the tank with a film of, I suggest you use 10 weight non-detergent oil, that's what we used in our motor frames, cause a little bit of oil in there is pretty good for protecting the inside of the tank. However it's advisable to never weld on this motor frame once you've put oil in it, and don't use any solvents at all that might be explosive, and never weld on this motor frame, and before you put the oil into the motor frame, after it's all welded together and put together, pressurize this motor frame up to the pressure that you would expect the motor frame to have, and we'll get into the pressures, also it would be a good idea if you had a safety valve on each one of the motor frames that relieves it at a considerable pressure below the point at which it would start to turn into a football instead of a square shape.

We've just about covered this motor, you can call it the pneumatic engine, you can call it the air motor, we don't care what you call it, we're just tickled to death that you're interested in reviewing it and looking at the pictures and hearing how it works.

The bolts we used on the rear for the pivot pins are code 9 heat-treated bolts, they go through the motor frames and are welded on each end where they go through the motor frames, and when you're getting ready to install these cylinders in your motor frames, you want to purchase your rod ends and put them on the cylinders, on the rod, and put them on the gears, and put them on the cranks, and actually check your top dead center and bottom dead center position to find out exactly, according to your dimensions of your rod end, where you want your pivot pin to be located. We have had instances where, to get everything to turn out right, we had to take your standard rod end that your striker is welded to, and grind a little material off that rod end, so that when you screw the rod end onto the cylinder rod, that it would change the dimensions a little bit, and sometimes after the pivot location and the code 9 bolt was welded to the motor frame, we might have to grind a little bit off the rod end to get your dimensions right, because you don't want the cylinder to bottom out either top dead center or bottom dead center, that's hard on your seals on your pistons, another thing is when you weld up your tank, and you think, well now, I'm ready to put it to use, do not hesitate to put 10, 20, 30 pounds of pressure on the tank and soap check, mix soap and water or dishwashing liquid in water, and make a bubbly mixture, and put plugs in all your ports that you have welded into your re-use tanks, we have several extra ports that will show up in our photographs, and these ports were in case the threads on one port go bad you could put a plug in there and use another port, and we also put extra ¼" pipe thread ports for instrumentation so we can take hoses off for pressure, but welders often, whoever's doing your welding for you, find someone that's a good MIG welder and caution them that when they go around and weld the plates on the tanks, that they don't just come up to the weld that's already there and stop, have them come up there and build a little heat and overlap the weld, and be sure that they build a lot of heat before they stop.

Same way with welding your air fittings on your tanks. You want to weld those pipe fittings, the pipe couplers that you cut in half and weld on the tank, be sure when they're welded on that your weld overlaps and that there's a lot of heat so you'll have the minimum of leaks. If you can weld this whole motor frame up, and then pressurize it, and not find more than three or four leaks, you'll be pretty lucky. I would say that your first motor frame that you put together, considering the fact that the steel tubing going through the motor frame, to hold your bronze bushings, plus all your fittings and your end caps, you'll be lucky if you can get this put together without having six or eight leaks, but the leaks are easy to fix, and then after you weld over an area that might be leaking, then pressure check it again, because if your motor frame leaks air, then you're gonna have air that you're not gonna be able to use in the engine. Now in the motor frame pictures of construction, we'll have another description of how the motor frame's welded together. Just real briefly, it's obvious that this whole thing is gonna be used as a tank, the 3" square tubing that you use at the bottom of this, and you weld onto the longest piece of motor frame, where that 3" tubing welds onto the side of the other 3" square tubing, you need to take a hole saw and drill at least a 1" hole through there so that the whole motor frame can be used to hold air.

The front plate on this engine that bolts to the firewall, that's pictured at the upper right hand side of this drawing, also has a piece of 1/8" thick rubber glued to it, and we also found that the area underneath the motor frame where the pivot bolts are for your rear pivot on your cylinders, that bolt that goes down through your carry-through on one of your front wheel drive vehicles needs to have a shock-mount on there where you've got rubber insulating the engine from the car frame. This is just to minimize noise. This engine has practically no vibration whatsoever, and the noise you hear is air, the timing unless you have a rubber washer where your striker hits the set collar, and then your gear noise. If you run the exhaust back to the tailpipe of the car, you know, into a tailpipe and out to the back of the car, when you're driving in the car the loudest noise you'll hear will be the gear noise. You'll hear the gear whirling along and we have audio tapes of the car driving where you hear a lot of exhaust noise and not so much gear noise, and we also have tapes of driving the car where we plumb the exhaust clear out the back of the car out through a tail pipe, and you hear very muted exhaust air noise, but you hear your gear noise. It's interesting the sounds of the pneumatic urban commuter, and they're unique.

But I do want to repeat, this engine can be built in four weeks with the information we have. You can vary the sizes and the stroke lengths and the gear ratio on the engine, but when we get into the theory of operation, you'll understand why it's essential to build the engine with your cranks being 90°out from each other, your crankpin locations, the one on your crankshaft gear and your crank. You'll understand why we have such a large crankshaft gear, it's because for every revolution of the crankshaft you want to get several feet down the road. The Spirit of Joplin Chevrolet has this engine in it, and the gear that is hooked up to this gear, and the oil-lite bushings at the bottom of this motor frame, is a 20-tooth gear, which gives you a gear ratio of one crankshaft gives you 7 on your constant velocity CV joint to your wheel, and your wheel is 5' 4" in circumference. Every time the air operating one of these cylinders, and it goes "choo-choo" as you count for every choo, you're going half of 38-1/2 feet down the road. And for every "choo-choo" you're going 38-1/2 feet down the road.

So we're in the process of coming up with multi-speed transmissions and we're really getting into the states now with international publicity on what we're doing, and we're handing out and disseminating information as quickly as possible, my name is Terry Miller, I live in Joplin, Missouri, and I can be contacted if you're in the midst of working on something. The reason we've come up with these descriptions of the engine and how to put them together and how to get the parts is that I'm 60 years old and I'm not as fast as I used to be, and I forget things once in a while, and I'm sitting here right now at home looking at this photograph #3, which was a series of step by step building photographs taken during the construction of these two engines, and it's somewhat of a trouble to stop what you're doing, say in the afternoon when you have the right kind of sunlight to take pictures, get your camera loaded up and get all the tools and extemporaneous material and notes and clutter out of the way and try and find a place to set the engine and select an angle at which you can take some pictures, knowing that a year or two or three years in the future these photographs that you took will be perhaps a valuable aid to other people and to engineers and to other people in other countries to learn how this engine works. While even I look at this picture and I wonder if I've told you everything I can tell you that will be of a benefit to you, if I tell you everything I know of that could be of benefit to you in putting this engine together, I do also hope that I don't neglect to tell you anything that might be a problem. It's really very simple, once you get started on it, and you can put two of these engines together, the smaller engine, and this is the larger engine, in four weeks' time, that's even getting started on it and getting your double-acting cylinders ordered from Bimba, and your WABCO spool valves ordered, and then when you get your cylinders in you'll know, even with your brochures, you can contact these people and get your brochures in within a week, and start on your motor frames and have these things put together in short order, and it's not all that expensive, and when you find the prices and you get into figuring the price for your air and your fuel and everything, you'll understand why we're very much enthused about it.

Let's go over things again, OK, the motor frame holds air, right? It has pipe couplers welded on at different strategic locations so you can put air into the tank and take air out of the tank which is also a motor frame, it's called a motor frame because it holds the tubing which holds the oil-lite bushings or the roller bearings if you will, for your crankshaft and also for your drive shaft, it's called a motor frame because it holds the code 9 heat treated bolts which serve as your rear pivot pin locations for your double-acting cylinders. Your cylinders are double-acting pneumatic cylinders, your spool valves again are 4-way spool valves with tapped exhaust, even though they're not all exhaust, I think they call them tapped exhaust, or tapped ports, with a closed center position, and your center port is your supply port, the parts are easy to name and find in the picture by now, there's your set collars or your collars that are used on the timing rods to adjust your timing and change your timing when your crankpin location and your extension and retraction of your double-acting cylinders is either at top dead center or bottom dead center, your striker is real simple and straightforward, there's your rod end, your crankpins are simply code 9 bolts, and we'll review the fact that the washers on either side of your rod ends are to keep your rod ends from rotating and allowing your striker to get tangled up in your gears or something else.

Your timing rods: this is something I forgot, and we're gonna talk about this right now. Once you get your spool rods from the supplier, and you want to figure out how to tie a ¼" rod to the end of the spool valve, you'll find out that you can go to the auto supply store and buy the cheaper sockets, regular mechanic's sockets like you put on a ratchet to tighten bolts, don't buy the very best heat-treated sockets because you're gonna need to drill a hole in them, but you can buy a socket of the right dimensions regardless of what country you live in, even if you're not using a ¼" rod for your timing rod, you could still find a socket and you could still find set collars and timing rods in whatever country you live in, and you could find a socket that will be a ¼" drive in this case, but it might be a metric drive in your case, which can be slipped on where it snaps onto a ratchet for turning the socket, you can slip the socket over the end of that rod and be sure it's lined up straight and weld it to the rod, and the end of the spool on each end of the spool valve has a hole drilled in each end of the shaft for the spool valve for a clevis pin and a cotter key. A clevis pin looks like a nail, and at the end of the clevis pin opposite where the head is, there's a hole drilled there for a cotter key. So if you slip this onto the end of the spool valve and you drill a hole clear through the socket that's welded to the rod that you're gonna use for a timing rod or push rod, you'll be able to use the clevis pin that came with the spool valve or have Rexroth send you extra clevis pins and cotter keys, you'll be able to slip the cotter key into the hole in the socket which is welded to the timing rod, onto the hole that's already drilled in the end of the spool valve shaft, on out through the other end of the socket, and then put a cotter key on there, and you'll have it all tied together so that your spool valve is bolted on your double-acting cylinder, the end of the spool is tied to the regular socket wrench, your socket wrench is welded to your timing rod, and so when the striker hits either one of the set collars since the two are fixed together, when it hits that set collar it will immediately move the spool valve. The spool valve that you're looking at right now requires only 5/8" travel to change the ports and the venting from push to pull in this case.

If you want to put a safety relief valve like they have on air compressor tanks on your motor frames, you can weld fittings underneath so your safety valve can be underneath and out of sight and not cluttering up the place. These rod ends are available from several different manufacturers, and as I said before, you don't want to just go ahead—the major mistake you could make would be to go ahead and take the dimensions from the brochures and just assume that the dimensions on your rod ends are all alike and assume that every double-acting cylinder from every manufacturer is the same dimensions and just lay this all out and make you a drawing and go ahead and weld your rear pivot bolts without physically checking them first, could prove to be a very costly mistake.

(side 4)

And you want to do this before you determine the actual location that you want to use for your rear pivot pin or rear pivot bolt location. Another critical dimension which will vary according to your engineering and whatever country you're located in, but to give you an example, this engine that is pictured here is an engine that uses double-acting cylinders, and the stroke length of our cylinders is 10" in length meaning that the rod end will travel 10" if you allow the cylinder to go as far as it will go. The cylinder manufacturer gives you a little leeway there, because they don't want you bottoming your pistons out against the end of the cylinder and possibly ruining the seals, but to eliminate this problem is very easy, whatever the length is of your stroke, if you have say an 8" stroke cylinder, then that would mean that normally from the center line of the crankshaft to the centerline of the crankpin bolt would be 4 linear inches from centerline to centerline. A 10" stroke cylinder like this, if you wanted your piston attached to the piston rod to go all the way to the front and all the way to the back of the cylinder, then if your stroke length is 10", then you would want your crank from the centerline of the crankshaft to the centerline of the crankpin bolt to be 5", however in the engine that you see here it has a10" stroke length on each cylinder, but the crank that you see on the 4" bore cylinder at the top of the picture, and actually the distance from the centerline on the crankshaft, from the center of the crankshaft on the crankshaft gear, out to where the bolt screws in to make the crankpin, that distance is 4-7/8", which means that when you reach top dead center, your actuating cylinder, the rod will be all the way extended out of the actuating cylinder except you'll have 1/8" of safety there to be sure that no way mechanically, unless something breaks, can your rubber seals within your double-acting cylinder bottom out.

Now you may have a cylinder where if you actually set it up, it would be a good idea when you take the cylinder out of the box, to actually set it up and push the piston gently all the way to the back and all the way to the front and actually measure the linear distance of your stroke length, because you may find a cylinder manufacturer whose 10" stroke cylinder is actually 10-1/8" or 10-1/4", which gets you back to the same point I mentioned before: the most costly or most delaying mistake I can see in coming up with your dimensions and putting it together would be to just go ahead and put your without actually checking the operation of your double-acting cylinder with a rod end screwed on tight and with the crank bolt screwed into your crankshaft gear or your crank. You want to do this and you want to feel it out and check it, and then very carefully centerpunch the location you want. You can actually stick a bolt through the bronze bushing at the rear of the cylinder, and when you get the cylinder where you want it and you hold it there, and you turn the crankshaft over a time or two and let the cylinder go ahead an suck in a little air through the ports, but go ahead and turn it slowly, and double check and find out that it's not bottoming out on either end, and then scribe line around your bolt or actually put a bolt through there that's machined to centerpunch, and precisely locate that rear pivot pin location so that when the double-acting cylinder operates, there' no way that you can take up more piston than you need to take up. This would be comparable to the thought of putting pistons with a dome inside a car, or pistons in a car engine that aren't designed for that engine, and having the piston hit the top of the cylinder head, or another similarity would be to screw the spark plugs down into the engine that were extra hot spark plugs, and screw them in so far that when the piston come up, the piston would hit the spark plug, you'd have a collision there. It would almost be as bad as having an excess of water in your cylinder when your cylinder when your cylinder was driven home, there's no place for the water to go. This is bad news and this is one think that's got to be right and it's easy to get right if you do it the first time. If you make a little mistake you can grind a little bit off your rod end that's on your rod, so it would screw on a little farther, or you can put a washer on it to make it a little bit longer, your linear distance between your pivot pin and your crank pin. That's what it all boils down to: it's the linear distance between your rear pivot pin centerline and your crankpin location on your gear or on your crank, and that linear distance, if it's right, and you double-check it at both top dead center and bottom dead center, then you have probably done the most important thing in putting this engine together, other than being sure it doesn't have any leaks and other you're your machinist does the machine work for your bushings and your tapping and threading that needs to be done.

In regards to the bearings that are used to hold the crank shaft and the drive shaft, we found steel tubing which was pretty close to the right dimensions to use the oil-lite bushings in it. That's the bronze bushings that are pressed together out of powdered metal by different processes, and they hold oil very well, and considering the engine rotation is anywhere from 0-50 rpm, you don't have any problem with the bearings heating up, and you press your bushing in, we used 1/8" wall thickness oil-lite bushings, and we used the oil-lite bushings that have a flange on one end of the bushing so that the gear and the crank can lay right up against the flange, and take a lot of slop out of it. We have motor frames we're putting together right now with roller bearings in them, and from what our engineers tell us, the roller bearings on the crank shaft and needle bearings on your rod end or even on your rear pivot pin location for your cylinder, your rear pivot bolt, could help; the general consensus of opinion is that at this low of an rpm, chances are that replacing your oil-lite bronze bushings for your crankshaft and your driveshaft would probably help more for the resulting power that the engine would put out. But we've all been amazed at how well the regular oil-lite bushings function and how well they're holding up. You think you hear a little slop in these bushings and all, so you disconnect from them, and you disconnect the driveshaft coupling from the driveshaft gear and the shaft, and you wiggle it in the oil, and you think you're gonna be able to wiggle that shaft in that oil-lite bushing, and then you find out that you can't wiggle it in that oil-lite bushing. So you find out that they're really wearing quite well.

This concludes the major discussion of drawing #3.

See if you can find drawing #4, and before we leave drawing #3 completely, if we can let's look at both of them at the same time, and there'll be one thing that's obvious when we look at them. If both of these engines say bolt to the firewall of the car, then the crankshaft is on the wrong or opposite side of one engine compared to the other engine, and the crank is on the wrong side—oh! Now we know what—we've got a left engine and a right engine. One drives the left wheel and one drives the right, let's figure out which. Let me see, if in drawing #3. We've discussed where the oil-lite bushing is down at the bottom of the gear, so we take a 1" shaft and we weld it onto a 20-tooth gear, 8 diametral pitch, 14-1/2° pitch angle, we press it through the gear and weld around the outside after we've pressed it through ¼" to be sure it stays on there, we oil it up and slip it through the oil-lite bushings, and then we're gonna want to tie the CV joint of a wheel to it, and if we put this engine in a car and run it out that way, and the plate on the engine bolts to the firewall, and the pivot pin location bolts to the carry-through at the front, then this engine, I mean the one in #3 drawing, is gonna be driving the right wheel. So therefore, it would appear that the engine in drawing #4, you can see the bronze bushing at the bottom, it's right down below the crankshaft if you measured it dimensionwise, in this engine if we welded up a 1" shaft to a 20-tooth gear, 8 pitch, 14-1/2° pressure angle on the gear teeth, and we slipped it through there with a gear on this side, it wouldn't work if we slipped it through from this side in drawing #4. So we'll have to put it around on the other side, and what'll be sticking out on this side toward us on the bottom right hand side of the picture or the motor frame portion that has an oil-lite bushing in it, when we slip the shaft in back toward us, and we take this engine then with the shaft sticking toward us and we bolt it onto the firewall and we put the back of the cylinders out toward the front of the car and we close the hood, the only thing we can tie to this shaft then will be the CV joint from the left wheel.

So drawing #4 has the engine, which is the left engine, and it drives the left wheel. Drawing #3 is the right engine, and it drives the right wheel. The reason we went after drawing #3 first in explaining all the parts and the nomenclature, is that drawing #3 is a little bit more complicated. It has hoses and other things added that you'll be able to understand now that we've been through the spool valves and the operation, we've been through all the nomenclature, so now's the time to set #3 drawing aside but maybe where you can glance at it, so let's discuss #4 drawing which depicts the engine which is set up to drive the left wheel. Boy we got a good view of the crank, in the lower right hand quarter of the drawing is the crank, and it's welded to the crankshaft. The machinist put a little indent in that crank, which is mild steel, with his cutting tool, to make it look a little neater. You can see the code 9 bolt very clearly screwed into the crank, which forms the crankpin, and there's a perfect picture there of the rod end with the striker attached, and the spool valve that you see on this cylinder, which is at the bottom of the picture, is the same size spool valve, a ½" spool valve with ½" pipe tapped ports. It has a detent kit on it and so does the other spool valve on the opposite side, except the spool at the top of the picture has ¼" taper pipe tapped ports instead of ½", and that's because the other cylinder uses a higher pressure, and we'll get into that real soon. So this engine is just the opposite, as far as left and right goes, as the other engine, except that there's some other things that are obvious if you look at them.

This drawing #4 shows smaller cylinders, which is necessary for the sequential re-use of air. The cylinder at the top of the picture is a 2" bore cylinder, and the power factor then is less than the cylinder at the bottom of the page that says Bimba on the decal which is upside down. When this cylinder is in the car, when you look down on the cylinder, you read Bimba a lot more clearly than you do in the picture; we did it that way on purpose. OK, the cylinder on the bottom of the page, the one with what looks like white hoses on it, they're actually yellow hoses, that cylinder is actually a 2-1/2" bore cylinder. And the one on the left, I said before, is a 2" bore cylinder, this one's 2-1/2" bore cylinder. Then you see your crankshaft gear, and if you go to the right hand side of the picture you'll see the plate, and you'll notice it's not put on there square, it's put on so it will fit the firewall, and this engine sits in at an angle and it's also cocked, so that the driveshaft going through the oil-lite bushing at the bottom of the picture will line up with your CV joints.

Now there's your plate, you can even see a couple of the bolts sticking through the plate which go into the firewall on the car. Now also you can see some air fittings along the top of the motor frame, right back from the plate on the right hand side of the picture about an inch back from the plate is an air fitting, 2" from that air fitting is another air fitting, and if you'll notice between those two fittings you'll see the nut on the crankpin, in other words, you have your crankshaft and this spoke on that gear ends up being your crank, and your crankpin is that bolt, and what you see is a nut on that bolt, so after we screw the bolt in through the washers which keep it from rotating too much, and through the spoke, then we put a jam nut on the back to cinch it up. If you'll notice too, considering the bolt going through the flywheel gear also serves as your crank, you get two for one, you get the flywheel gear and the crank in one unit, if you'll notice, it is 90° out as far as clocking, you'll notice that your cranks are 90° out in degrees of rotation or in clocking, so that when one cylinder on this engine also is at top dead center, then the other cylinder will be out, and when that cylinder is at bottom dead center, the other cylinder will be out, or vice-versa.

Both these cylinders are single-wall, stainless steel, Bimba cylinders, and a very good picture now at the bottom of the picture, go to the center bottom of the picture, come up about 2" and there is a very good view of the jam nut, which is a large hex nut, screwed onto the thread of the front mount bracket. The front mount bracket is what looks like a piece of angle iron sawed off, but it's the front mount bracket modified and made to fit for this application, then there's the 3/16" steel plate that's welded onto the front mount bracket, and that jam nut tightens it up and holds that plate and the spool valve bolts to the plate, we've been through that. Look right above the jam nut, on up above the motor frame, and in the very center of picture #4, and you can see the mount bracket and just a little bit of the jam nut. Now the jam nut and the mounting bracket are smaller because the cylinder is a ½" smaller in diameter, and the spool valve's linear dimensions for length and width and height and all is less because it's a smaller valve, it's ¼" pipe threads, and we selected that in the Spirit of Joplin car because often we call upon this cylinder to accommodate and handle higher pressure, up to 500 psi pressure we use occasionally in this cylinder.

You're beginning to wonder surely by now, different cylinder sizes, and most of you by now interested enough to go this far into studying the engine, will know by now what we're doing. What we're doing with these two engines is we're compounding air, just like a compound steam engine, but air does not have the continually expanding nature of steam, however we have figured out that if we run this engine slow enough, at an ideal rpm of 40, we have the time to save and re-use the air. So the cylinder at the top of these two cylinders in picture #4 is the first to use air, then it goes into the motor frame, which is an air tank, the air that exhausts from the spool valve after being used to either push or pull that cylinder goes into the motor frame, then the air is allowed to come out of this motor frame and into the pressure port on this 2" bore cylinder at the bottom in this picture. You see a black hose, and you can see a fitting on the motor frame, and the black hose goes up at the left hand side of the picture, makes a u-turn and comes right back down into the pressure port on the cylinder. Then once the spool valve moves, whichever position the spool valve's in for push or pull, allows the two hoses that come out next to the black hose fitting on that spool valve on the cylinder closest to us, you'll see the hose comes out of the tapped pipe ports on the spool valve and goes down and into your port on the cylinder, and the other one, you can't see it go into the port of the cylinder, but where the jam nut is that holds the mounting bracket on this 2-1/2" cylinder at the bottom of the picture, you can see clearly the hose going from the air port on the cylinder and on into the spool valve, that only leaves two other ports on this spool valve, and you can see the hose is coming out, tying together in a "T", and this is where you save the exhaust air coming out of the cylinder that is plumbed and ported and vented out of the cylinder, through this spool valve, and out and into this "T." And this air coming out of this "T," having been used in the first cylinder at the top, the 2" bore, and then the exhaust collected and put in this motor frame tank, and then the air coming out of the motor frame tank and into the spool valve on the 2-1/2" bore cylinder at the bottom of the picture, and being used here, then the air after being used here comes out into these hoses and you see the "T" at the lower left hand of the picture, and that goes into the motor frame of the right hand engine driving the right hand wheel, and it goes into the motor frame that you see in drawing #3.

Then the air comes out of that motor frame and it goes into the spool valve you see pictured, and we're gonna get into a breakdown of that a little farther when we get into the full engine drawing, but I hope you have drawing #3 where you can look at it, and the air goes from this 2-1/2" cylinder in drawing #4, out through the spool valve and goes into the motor frame in drawing #3, and is used the same way: the hoses aren't on the cylinder in this drawing, but the spool valve controls the venting and porting of the air, and the air comes out of this motor frame, and is used in this 3" bore cylinder, then the exhaust air goes to another tank that goes crossways underneath the engine from wheel well to wheel well, and that air is allowed to come out of that tank and into the spool valve for the #4" cylinder, which is the last to use the air, and then that air is vented to the atmosphere. Drawing #4: if you'll notice that the upper cylinder in the drawing, as I said the jam nut that holds the bracket is approximately in the center of the drawing, the plumbing on that particular spool valve, the manifolding that saves and collects the exhaust air is made of brake line material and steel tubing, and it's smaller and higher pressure, and this will show up real good in our engine drawing that we'll get to pretty soon, but your exhaust out of #1 cylinder spool valve, this is the only drawing that you have before you that shows how the two exhaust ports are plumbed together. That plus looking at the spool valve on the cylinder at the bottom of the picture shows how the exhaust ports here are plumbed together with hose, and the 2" bore cylinder spool valves are plumbed together with steel tubing, it's just smaller and it was just easier to do that way. It's readily apparent that we save and re-use the exhaust air from one cylinder, and re-use it in the next cylinder, and then re-use it in the next cylinder, and use it in the next cylinder.

It is this sequential re-use of air that allows us to get the maximum benefit, and to get the most of the kinetic energy of the air. These cylinders are progressively larger. The top cylinder in drawing #4 is 2" in diameter, the bottom cylinder is 2-1/2" in diameter, the cylinders in drawing #3 are 3" in diameter and 4" in diameter. So the pressure drops as we use the air, and as the air comes out of one cylinder and goes into your motor frames which are also re-use tanks, the pressure drops. So in order to get the same force or close to the same force on the cranks, we have to go to the next larger size bore cylinder The total Pneumacom project is proceeding along smoothly. We're into flow bench operations select the optimum cylinder bore and stroke lengths to get the maximum of the kinetic energy out of the air and the air receivers on-board the car. We hope to have production prototype engines available no later than January in the first of this year 1995. There'll be an engine that can be fitted into several different front-wheel drive vehicles. There'll be a left and a right engine and a person can purchase one engine set up specifically to be theory engine to explain how the sequential re-use of air works. By selectively alternating the sizes of cylinders in a theory engine, a lot can be learned, and then the engine can also be used with another engine to drive both the left and right wheels.

(side 5)

I'm Terry Miller, I'm a resident of Joplin, Missouri, and the president of Pneumacom Corporation. Toby Butterfield, also of Joplin, is the vice-president of Pneumacom Corporation. We also have a club here in Joplin called the International Pneumatic Commuter Club, the Joplin chapter, and we've been teaching school this summer. We have a school named the Joplin International Autopneumatics Institute. It is our goal, and we seem to be succeeding at it, to teach our pneumatic commuter technology around the world, and we're very fortunate to have a fairly detailed description of our sequential re-use of air technology published in several trade magazines that are distributed all around the world, hence we're getting a lot of phone calls and a lot of letters. Our address for all our endeavors, both the club, the corporation (Pneumacom Inc.) is 511 Main, Joplin, Missouri, 64801, and our corporate office phone number, available five days a week, is 417-624-5585.

This presentation that I'm making is the wrap-up of the presentation on some pictures—I'd like to bring out the fact now that when you take a beautiful glossy color print of parts of the pneumatic engine and they are photographs, they are really pictures, and then when you make a Xerox copy of it, and the quality of the endeavor is somewhat diminished, even though the detail is there, somehow in my mind I look at them and I call them drawings, once we make a copy of something, then the machine "drew" this picture, I'm 60 years old, I call them drawings, I'll probably call them drawings the rest of my life, but other than that we'll try to get the details correct for you.

If you are in receipt of an engine drawing showing the front end of a Chevrolet Sprint with the two engines that we have talked about, on drawing #4, drawing #3, and drawing #5, the engine drawing I'm not going to number, and the reason is, we may updated drawing to go with this text, maybe a little different dimensions or something, maybe in a Ford Festiva or a Ford Aspire vehicle that we hope to be working on soon. If you have a copy of any of these engines drawings of the engine in the car, the description explaining how the air goes through the engine and how the air is re-used, the particular drawing that you have will suffice. If you'll look at the left engine, in the vehicle, if you're sitting in the driver's seat, the left engine will be the one that's in the uppermost part of the sheet of paper that you're holding. The engine has one large gear on it with multi-teeth that we've talked about before, and the right engine also has a large multi-tooth gear. A lot of people call it the flywheel gear, which is all right, however at 40-50 rpm, you can easily see that there's no such thing as a flywheel action here.

Along the top of the motor frame, you'll notice there's a dark hose in this black-and-white drawing, that comes out of the firewall, and there's a bolt at the top of the firewall, and there's a hose clamp holding the hose, and the hose goes up slightly off the motor frame and is tied back down to the motor frame, and it's visible between the spokes of the left hand engine, there's a hose clamp there that clamps the hose down against the motor frame. Then roller-coaster style, the hose comes on down over the top of the motor frame and goes up and loops down and comes into the spool valve, and this might throw you a little bit, because I'm gonna tell you that it goes into the spool valve for the #1 cylinder. Now if the right engine's cylinder is 3" in diameter, and the next one is 4" in diameter, and I tell you that the #1 cylinder is 2" in diameter, and the #2 cylinder is 2-1/2" in diameter, then you might be concerned or wonder about the placement.

The placement of these cylinders has to do with their dimensions. The 2" bore cylinder, which I've just described the black hose going up roller coaster style and curving down to the center port of the spool valve located on the top of the #1 cylinder, which is the 2" bore cylinder, the reason for that is that particular cylinder is a longer cylinder in its body, even though it is a 10" stroke it is longer in its body, and therefore we had reason to put it there because we needed to clear the brake's master cylinder for the hydraulic brakes for the vehicle, and it just so happened that we needed an extra 3/4" that the 2-1/2" cylinder, or second cylinder, would give us. Otherwise, if it hadn't been for the constraint of space, the first cylinder to use air, the 2" or #1 cylinder, would have been the farthest to the left and the closest to the left front wheel and the wheel well of the vehicle. So here we go. We have the cylinder, which is a double-acting cylinder with the spool valve mounted on top, as we have discussed and explained in drawing #5 and drawing #3 and drawing #4. This particular spool valve has ¼" tapped pipe thread ports, and the cylinder in more detail is shown in the other drawings, however, this engine drawing in the car for the left engine shows you a lot more of the hoses hooked up.

Now the spool valve besides having that one particular hose that's hooked up to the center port of the spool valve comes directly from a regulator, a welding-type regulator sold by Victor. It is a regulator capable of cranking up to 1500 psi, and it will handle a manifold pressure of 4000 psi. It is simply a welding-type regulator, and when you screw the T-handle of a regulator in like a faucet, instead of turning off the water or the gas like your manifold valves on your tanks do, or the faucet in your wash basin at home that has a screw-in process, when you screw in the screw thread on a regulator, you actually increase the pressure. So a regulator, as far as the rotation of the T-handle or the handle, works just the opposite of a faucet. So we have the regulator between the seats of the car. It's mounted where either the passenger or the driver can reach the t handle. You can reach the manifold valves usually while still sitting in your seat, unless the tank is mounted on the roof of the car, in which case you have to turn them on and off while you're outside the car.

So here we are, we can discuss air tanks in the car later, let's go through how the air goes through the engine, and what happens after it goes through this engine. All right, the air going into this spool valve, shown in a dark color which happens to be a black hose, goes into the spool valve and according to the striker, however it hits the set collars on the timing rod, which is tied to the spool in the spool valve. The spool valve is set up direct and allows the double-acting cylinder to either push or pull, so once the air is ported into the push or the pull port on the cylinder, then the next thing it does when it changes and reverses the flow, so that one port on the cylinder for a while becomes the pressure port for driving the rod and giving you the force to turn the crank, and in the next instant once the spool valve shifts, the pressure port in the cylinder becomes an exhaust port, and the air backs out of the hose, first it went in under pressure, and now it reverses and goes back out of the hose. Because the spool valve has shifted over, it goes out one of the exhaust ports on the spool valve.

As shown in drawing #4, the exhaust ports in the spool valve are tied together and teed together so both exhaust ports comes into one hose, and that particular hose comes around and goes into the check valve that's located, and you can find it, the Chevrolet insignia on the center of the grill of the car, and the black hose where the intake port is on the spool valve, on the top of the motor frame you'll see the piece sticking up there in the fitting, and that is a one-way check valve, so the manifolded exhaust of the air that has been already been used to push and pull the double-acting cylinder or #1 cylinder, and once it exhausts out of the cylinder at the time that it's being used as an exhaust port, and back through the spool valve, and collected in that manifold, or your re-use manifold, then the hose from there, you can't see all the hose, but you can see the black hose looping up again and down and into that check valve, and that check valve is affixed to and screwed into one of the pipe couplers which was cut in two welded to the motor frame.

We have discussed previously that the motor frame serves as a re-use tank to hold pressurized air, so we have operated this double-acting cylinder, the first cylinder to use air, and as the ports on the double-acting cylinder automatically alternate between pressure and exhaust, and the exhaust air, once the hose changes from a hose supplying pressure to one supplying pressure in exhaust, and through the spool valve and out through the manifold and into the re-use tank, then the air in the re-use tank, which is also the left-hand engine motor frame, once it's into the re-use tank, then it can be drawn out of that tank and used again somewhere, and we'll do that. But first, before we take the air out of the left hand re-use tank, we're gonna consider a few things. Since the air is stored in the car, in aluminum tanks that are carbon-fiber wrapped to be lightweight and hold a whole lot of pressure, or this kinetic energy in these tanks is manifolded together and comes to the regulator and is regulated, and the first cylinder to use this air determines how much air the car uses as it goes down the road when you figure in some other factors.

The particular vehicle that was the real successful vehicle, called the Spirit of Joplin, has two pneumatic engines in it: one drives the left wheel and one drives the right wheel. The engine that drives the right wheel, or the right engine, has nothing to do with the initial use of air. What has to do with the initial use of air is the initial cylinder to use the air, and that is the #1 cylinder, pictured on the right hand side of this left-hand engine motor frame, it's the 2" bore cylinder, 10" stroke. Now, every time that cylinder goes choo-choo back and forth, and every time the striker hits the set collars on the spool valve timing rod, and it hits the set collars, and you've made one complete revolution of the crankshaft gear. Depending on the gearing, and in the Spirit of Joplin car, the Chevrolet Sprint, it is geared with a 140-tooth gear driving a 20-tooth gear, so every time the crankshaft goes around, I believe we have mentioned this in the tape preceding this one, the car actually goes 38-1/2 feet down the road. So, if the cylinder is gonna go choo-choo, and the hoses supplying the pressure are gonna change from pressure hoses supplying kinetic energy to push the piston to give you force on the cylinder rod, and that force to the crank, which gives you a turning action, or torque, and that torque is transmitted from the crankshaft gear to the driveshaft gear, and it's all tied together, then there's a certain amount of volume that this #1 cylinder is allowed to take in every time you go 38-1/2' down the road. It would also take in a certain volume of air every time you went a mile down the road, or every time you went ten miles down the road.

So let's stop and think what would be the other factor that would determine how much air this vehicle is going to use. For all practical purposes you can take the 2nd cylinder, and the 3rd cylinder, and the 4th cylinder, and the 5th cylinder, and the 8th double-acting cylinder, how many cylinders happen to be in different engines driving this car? If all the cylinders down the line are gonna use the same air that we just got through putting into the first cylinder, and they're gonna use the same air with the desire or the assumption that they're gonna be able to go to a larger size in diameter and increase their power factor and still be able to deliver a sufficient amount of force on the crank, which is turned into a rotary action on the crankshaft gear, there's got to be another factor that's gonna determine how many cubic feet of air at atmospheric pressure like you and I are breathing right now, how many cubic feet of air is gonna be eaten up every time this car goes 38-1/2' down the road, or how many cubic feet of air per mile. Or how many cubic feet of air to come up with a vehicle that will go 50 miles at say 30 mph. The other factor that determines how much air this car will take in with this gear ratio using a 10" stroke cylinder with a 2" bore is simply the pressure of the air that's going in that black hose that we described that goes underneath the hose clamp tied to the motor frame, into the center tapped port, or the pressure port, on #1 cylinder.

So if we just simply disconnected the fitting on the top of that spool valve, and rolled the car down the street, and we rolled the car very slowly, say maybe just a mile an hour, and we disconnected this hose, and we allow this cylinder with the rod end and the striker operating the spool valve, so that as you push this car slowly down the road, the spool valve sitting on top of that #1 cylinder with the hose disconnected, could go in and suck air in every time for push and pull, and allow the exhausting of the spool valve, to go ahead and let the exhaust go into the #1 engine re-use tank, and we pull the plug, one of those plugs right on top of that #1 engine re-use tank, the one the high pressure hose goes into from the regulator, there's one plug there, we could just pull that plug, so as we went down the road the cylinder's drawn back just like a pump, like a tire pump, when that cylinder actuated it would cause a vacuum and the air would come in at the top of that spool valve where we had the hose disconnected, and once it went through the cylinder and went through the spool valve, it would go into the motor frame which is the re-use tank for the left engine, and the air would exhaust out there, and we're pushing the car very slowly.

Now, in this particular instance, with no pressure on the air, just enough to suck it in there and blow it back out the exhaust and on through, if you had some way of measuring this, you could get very accurate data on how many cubic feet of air at atmospheric pressure you would take in every time you went 38-1/2' down the road. This can also be done mathematically, you can figure out how much air your hoses carry, because from each spool valve to the cylinder, you have to have a hose or on this particular one a steel tubing plumbed from the two pressure ports on the spool valve down to each port on the cylinder, and those ports as I said before are alternately the pressure and exhaust hoses, but you could figure out the capacity of those, knowing that when the spool valve changes over, the air that's in that will be lost, it won't go on into the cylinder, it will stop where it's at and go back out into exhaust, and you could figure out the internal volume of the double-acting cylinder and come up with a pretty good equation as to how much air this cylinder would take in and exhaust due to the volume of the cylinder, measured in cubic inches or whatever depending on what country you're in. This would be pretty easy to compute. It's rather insignificant, though, because this car, and this particular cylinder, and the one's we're going to build in the future, operate on air pressure, or the kinetic energy of the air.

So it stands to reason that the black hose that comes out of the firewall and through that a-dell(?) clamp that has a bolt through it, and clamped to the motor frame with a hose clamp, and goes roller-coaster up and down and into that spool valve, that particular hose right there, if you had the regulator set at 500 pounds of pressure, that hose would have 500 pounds of pressure in it, and none of that air would be used until the car started to roll, and then the porting and the venting of the spool within the spool valve on top of #1 cylinder would tell the cylinder and would deliver to the cylinder either pressurized air on the pull stroke, while allowing the air that had already been used to push, to exhaust, and be constantly changing that, hence that's the name that the spool valve has, it's a 4-way spool valve, 4-way meaning you've got one hose that ends up being alternative pressure and exhaust, and another one that ends up being alternative pressure and exhaust, you've got a 4-way action there. But if you had 250 pounds of pressure in the hose, you would have air that had been condensed, or compressed, and confined in a smaller area, and the molecules in that air are trying to do work and they're trying to escape, and they're bombarding the sides of the hoses trying to get out and back to mother nature. If that hose had 500 psi in it, chances are that hose would contain in every linear inch of hose would probably contain twice as many cubic inches or cubic feet or cubic whatever depending on the country you reside in. But the point I'm wanting to make is that the other factor then that determines how much air you use when you roll down the road, it wouldn't make any difference if you had a tractor on the front of this car, and that cylinder say wouldn't have enough power to drive the car, but you would like to know how much air it would take at say 250 psi, you could hook a tractor and a chain onto that car and you could pull it slowly down the road at 5 mph or 10 mph or 2 mph and if you had the same pressure on that cylinder, whether it was 200, 250, 300, 500, the pressure would be the other factor that would determine how many cubic inches, cubic feet, or whatever it's called in your country, how much air could be used in that first cylinder if it went choo-choo every time you went 38-1/2 feet down the road.

So, the gear ratio of the car, meaning how many feet it's geared to go every time the cylinder actuates one time completely, push and pull, the volume of the cylinder is how much air it would hold at different pressures, and the pressure of the air you're using at the time, it stands to reason that if you used 200 psi and you drove the car on this one cylinder alone at 200 psi, and believe me, the car will roll, this vehicle will roll with only that one 2" bore cylinder hooked up. It will drive on that one cylinder only. And if you're driving that car on that one cylinder only and you're making it roll, it will use a certain amount of air at 100 psi, it will use probably twice as much air at 200 psi, 3 times as much air at 300 psi, 4 times as much air at 400 psi, and probably 5 times as much air at 500 psi. All right, now don't hold me to this, but this is by way of explaining that the amount of air pressure your air is at, at the time it is run through this first cylinder, is one of the determining factors that determines how much air you will use.

(side 6)

Go ahead and take this first air from the regulator, and put it in the 4" bore cylinder, which cylinder is gonna use more air at 100 psi? They'll both drive the car at 150-200 psi. But let's put 200 psi on this 4" bore cylinder, it will drive the car, and it will drive the car with more force, and more speed, and have better hill-climbing ability and everything else, because it will have a power factor three times what the 2" cylinder will have. Because as cylinder, say from 2" to 4", you think the 4" diameter cylinder will be twice the power factor of the 2" diameter cylinder. This is not so. When you figure up the square inches of surface area that the air has to push against, on the piston in the 4" bore cylinder, that 4" bore cylinder at 200 psi is able to deliver much more force at the crank than the 2" bore cylinder is able to deliver.

So let's just figure we'll drive the car for a mile with only the 4" bore cylinder on the right hand engine connected, and it's using the air for the first time. It's obvious that the car will have a little more power, and it will go farther, no it won't go farther, it'll go less if you use the same amount of air, let's just say it will have more power and will move a little faster because you'll have a cylinder able to deliver more power. Let's say we're using 200 psi. Well the 2" bore cylinder #1 located on the right hand side of the number one motor frame or the 4" bore cylinder on the right hand side of the right hand engine, they'll both be able to drive the car, but the 4" bore cylinder because it is larger, the only factor then we're changing in the equation, the gear ratio is the same, right? 140-tooth gear driving a 20-tooth gear driving the wheel. The stroke lengths are the same, the distance we'll go down the road is the same, the only thing that's gonna change the amount of air that we use is the size of the cylinder. If we wanted to use two cylinders and they were both 4" bores, and we tried the air in one cylinder one time and tried the air in the other cylinder the other time, and let each single cylinder drive the car, then we would use less air—and this requires a little bit of thought now—if we had two 4" bore cylinders, one on the left engine, one on the right engine, and had all the other cylinders laying on the bench not being used, and we had a 4" bore cylinder tied to the crank of the right hand engine, and a 4" bore cylinder tied to the crank on the left hand engine, and we put 100 psi on both cylinders, both cylinders would use the same amount of air to drive the car a certain distance at a certain pressure.

But if we change the pressure, and we drove the car on the 4" bore cylinder at a certain pressure, say 100 psi, and then we drove the car on the other cylinder, say at 200 psi, we would not get as far down the road with the cylinder that was using the air at 200 psi, because every foot down the road, every inch down the road, we would be eating up more air. We would be going faster, granted, because we'd have twice the force on the shaft, pushing on the crank, turning the crank, turning this force into torque to transmit from the flywheel gear, or the transmission gear, the crankshaft gear to the driveshaft gear and out to the wheels of the car. So we get right back to it, it takes a little thought, the 2" bore cylinder is the first cylinder to use the air, and it's the first cylinder to use the air for a reason. We use the air at up to 500 psi. And we have a lot of kinetic energy in the air. We don't want that cylinder to be big, because if it's big, we'll use up all the air the first shot, and there won't be any way to use it again. So we use the small 2" bore cylinder the first time, and whatever air pressure we use, about half of that air pressure is saved in the left hand re-use tank, which is the motor frame for the left hand engine, now that motor frame for the left hand engine therefore supplies compressed air at roughly half the pressure that we were putting into the #1 cylinder.

We see the check valve there, just behind the Chevrolet emblem, and the fitting going down into the motor frame, in this particular instance we don't see a hose coming out of the left hand motor frame going to the #2 cylinder spool valve, but there is a hose going in there, we can see just behind the Chevrolet emblem, just about an inch up on the drawing, on the Chevrolet emblem on the grille, about one inch up we can see the hose looping and and going down into the center port. It's a black hose, we can see the light shining on the black hose as it loops up by the left headlight and comes right down into the top of that spool valve, and it is a wire-braided high pressure hose, which is the last high pressure hose to be used in this engine system, because we drop down to lower pressure hoses, which are more flexible. So there is the hose that's taking air out of the left engine re-use tank, the motor frame, and putting it into the spool valve for #2 cylinder, and in that place, that spool valve sitting astride that double-acting cylinder like a saddle on a horse, it being timed by the striker that's welded to the rod end and the striker sliding up and down the timing rod, hitting the set collars, bumping against the set collars, and the timing rod being affixed to the spool valve shaft, that moves the spool valve back and forth and changes the venting and the porting of the air to cause that cylinder to go choo-choo, and to go push-pull, just like the #1 cylinder did. However, this cylinder is a 2-1/2" bore cylinder, so it is enabled to deliver a considerable amount of force to the crank because the power factor of this cylinder is larger.

So we have taken the air that's used in the first cylinder, 2" bore, put it into the left hand motor frame, stored it there under pressure, let the air come out of the left hand motor frame via the hose, down into the pressure port, the center tapped port of the spool valve on top of #2 cylinder, be used to drive that cylinder push-pull, by venting and porting the air, then we save the exhaust air that comes out of the two exhaust ports on the spool valve—now that's a good time to mention that the spool valve does have two exhaust ports on it, and they are the two ports farthest away from the center pressure port where you supply pressure to the spool valve. And the spool valve selects two other ports, to allow this pressure to pass over to them, through the indentation in the spool, and these other two pressure ports supply air pressure via the hose to the port at the front of the double-acting cylinder and at the back of the double-acting cylinder.

Then when the spool valve changes over and tells the cylinder no, the hose that was supplying pressure to the pipe-tapped port at the front of the cylinder, we just got through supplying pressure, and we've pushed the piston to the back, and we've been on the pull stroke, but now we're changing around and we're letting that hose change from a pressure hose to an exhaust hose, and the air will back up through what used to be the pressure port on the spool valve due to the fact that the striker hits the set collars and moved the detent in the spool to where it connects that port to the exhaust port, then it also connects on the other side, it changed the port that used to be an exhaust port into a pressure port, and now you're allowed to reverse the flow in the cylinder and allow the cylinder to have pressure at the back side, pushing the cylinder to the front, and putting the cylinder into the push mode. It is a 4-way spool valve, pressure, center, tapped ports. And in the center position of this spool valve—the actual spool in the ½" valve slides 5/8" to do all this action, and that's not much, 5/8" to change the spool valve ports from pressure to exhaust, or from exhaust to pressure, and it does this very efficiently, one of the greatest spool valves I've ever encountered, and absolutely it seems that the WABCO, which stands for Westinghouse Air Brake Co., this is an old spool valve, designed many many years ago, and it has been invaluable in the work that we're doing, and we highly recommend it. It's distributed by Rexroth Worldwide Pneumatics, it's just a super spool valve for this application. You may think that we've spent an awful long time on the left engine, but bear in mind that both engines, the left and the right, are sequential re-use engines, and they both use the air in one cylinder, and save the air that was used in that cylinder on that engine, and put it in a storage tank somewhere, and re-use the air in another cylinder on the same engine that has a larger bore and a larger power factor.

What keeps the air from going back, where you don't want it? All right, let's go back to the check valve, and the only one showing up on top of the engine, there are other check valves in the hoses, that go underneath the engine, and they go underneath the left engine and underneath the right engine. But let's find the Chevrolet emblem at the top of the grille on the car, and let's go to the left of that Chevrolet emblem, what would be about an inch-an-a-half linear measurement, and you'll see the spool valve tied to a pipe coupler that was cut in half and welded to the left engine motor frame combination re-use tank, anyway, that check valve screws into the pipe coupler fitting, and it allows the air that's going out of the spool valve on #1 engine and into the manifold, which shows up pretty clearly, that manifold that we're talking about, on drawing #4, you can see the two spool valves that we're talking about, that are located the farthest away from the center pressure port that comes up out of the top. Anyway, those exhaust ports are plumbed together, and the black hose circles around from that manifold and goes up and down and into that check valve and supplies air to the left hand engine motor frame/air re-use tank.

Now, the check valve has a reason. It isolates the air, the exhaust air from #1 cylinder into the left hand engine re-use tank. Boy, we're spending a lot of time on the left hand engine. But once we get the left engine operation down, the right engine practically doesn't need any talking about. One is the same as the other. Now, the check valve keeps the air from backing out of the re-use tank and driving the #1 cylinder in a direction you might not want it to drive, or it isolates the kinetic energy in the re-use tank. Once the exhaust air passes that check valve, it stays in the re-use tank. Now, the manifold that collects the air, the hoses manifolded together that collect the exhaust air from #2 cylinder, that manifolded air goes through a hose via check valve and crosses underneath the left hand engine motor frame, and goes into the right hand engine motor frame. Now if you'll look at drawing #5, you can find probably the best drawing of the hoses for the #2 cylinder on the left hand engine motor frame. Again, that drawing #5 is kind of confusing, you get to thinking that the engine you're talking about is the right hand engine, but it's not. At the top of these two engines sitting there in drawing #5, the cylinder you can't see, that's down, the stroke position is just off of the dead center position, you can see the spool valve, but the only portion of that valve you can see is just a little bit at the back by the pivot point. But anyway the bottom engine on drawing #5 is the left hand engine motor frame, and the spool valve to the 2-1/2" bore cylinder, and the hoses for it which are right down at the bottom of the picture, are very clear. You can see another picture of the check valve going into the motor frame, you can also see at the top of the left hand engine motor frame, you can see 1, 2, 3, 4 extra pipe couplers that were welded onto the tanks for optional use and for instrumentation, but that check valve is right there, and if you'll follow out of the top of the check valve, the hose goes up and makes a left, goes down and turns to the right, and goes right into the steel tubing and the two steel fittings that make up the manifold 16, or the re-use air manifold out of the spool valve on #1 cylinder. There's a very good view of it.

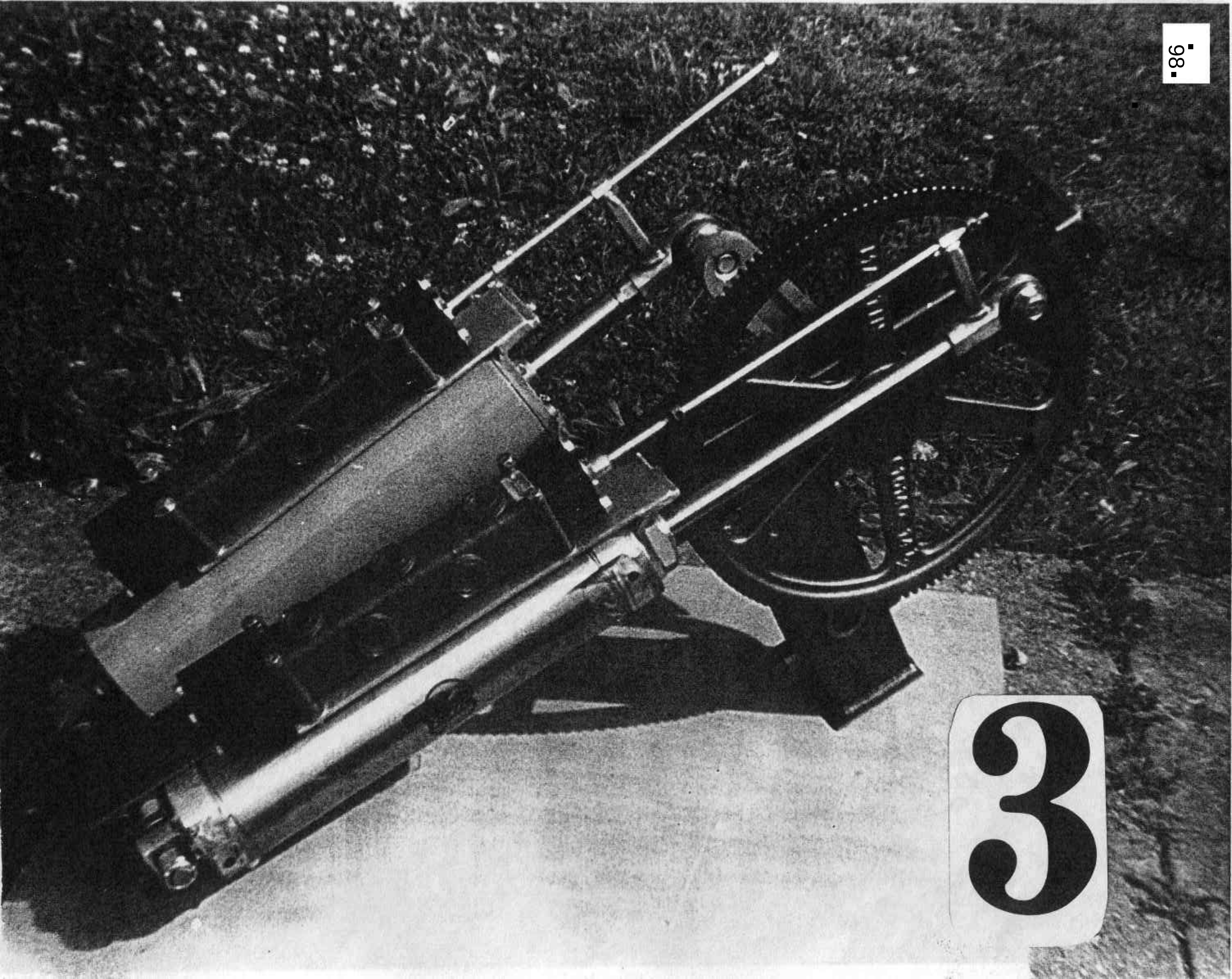
Also, you can find about one inch to the left of the check valve, you can see the hose fittings screwed into the pipe coupler, welded to the left hand engine motor frame, and you can see the hose on the hose coupling go up and make a u-turn, and come right down, looks like back toward you, and right down into the center port on the spool valve, on the 2-1/2" bore, #2 cylinder, on the left hand motor frame, and there you are, you got your ports laid out there. There's your black or your dark hose going into the top of that spool valve, you can see to the left and the right, the two pressure ports, they're alternating pressure and exhaust ports where the hose comes out of there and goes into the back of the cylinder to supply air for the push stroke, and also exhaust air out through the manifold for the pull stroke, you can see to the right of that manifold the hose there, which in the pull stroke will provide air pressure to the front of the cylinder, pushing the cylinder back for the pull stroke, and then when the spool valve actuates, you can see and visualize how the striker would hit the set collar and move the spool, and then that hose which would normally have pressure for driving the cylinder would have re-use air pressure, or exhaust air pressure, which would go out the exhaust port, and you can see the manifolding, what we call manifold 16 two times in this drawing #5.

If you'll look at #2 cylinder you can see the hose that comes out of the exhaust port at the front of the spool valve, you can see the hose coming out of the exhaust port at the back of the spool valve, you can see the T-fitting where the two hoses tie together, and you can see a length of hose just curl up, the end of the hose curls up and points to #2 cylinder, and it hasn't been hooked up yet, but when these engines are put in the car, this hose will go over, it will go through a check valve and then into the right hand engine combination motor frame and re-use air tank. And then the air will come out of that motor frame, the right hand re-use motor frame, and into the center port of the spool valve, and we start the process all over again. So we can go back to our engine drawing and maybe keep this drawing #5 handy to look at. The re-use of air means once we put the exhaust air from one cylinder into a re-use tank, we need a check valve to keep the air isolated in that tank, and then the only way the compressed air can get out of that tank is via a hose to the next larger cylinder. That way we do our best to get the same amount of force to each crank as the first crank, we try to get the same amount of force on the next crank and then on over to the next engine.

Now, I might add that these two engines are separated mechanically. The right engine does not drive the left wheel, and the left engine does not drive the right wheel. So in this particular case we do not need a differential, in case one wheel is running faster than the other. In this particular engine setup, if you're turning left, the left engine will have less distance to turn because the wheel will be turning a shorter radius than the right wheel, and consequently the left engine won't be running as fast as the right engine. If you turn right, then the left engine will either be running faster, or depending on how you look at it, the right engine would run slower. So they're not tied together mechanically, however the exhaust from cylinder #2 goes underneath both motor frames and goes into the right hand engine motor frame, then air comes out of the right hand engine motor frame and we can see, if we'll locate the spool valve on the paper just about an inch above the right hand headlight on the car, if you see the spool valve there just to the left of the right hand engine motor frame, we can't see the shaft from #3 cylinder, and we can't see the rod end from #3 cylinder, but we can see the timing rod that protrudes out from the #3 cylinder spool valve, and we can see the two bolts at the front of the spool valve, which bolt the spool valve down to the plate, and lets the spool valve sit on top of the plate, which is tied to the front mounting bracket on the cylinder by use of the jam nut, all right, the spool valve sitting there, between the two nuts we can see the Westinghouse Air Brake name plate on the spool valve, now if you'll note just slightly above in the drawing of that nameplate on the spool valve where the two front bolts bolt the spool valve to the plate, you'll see a hose coming out from the area which would be the front tapped port of the 3" bore cylinder, the #3 cylinder, the hose comes out and makes a u-turn and comes right back into the pressure port of the spool valve, then you can see the other pressure port of the spool valve to the right, about an inch, and you can see the hose come out of there and make a right u-turn back, and you can't see it because it ducks under the grille, but it's heading into the tapped air port at the rear of the #3 double-acting cylinder.

Now, the hose coming out of the right hand engine motor frame/air re-use tank, you can see it going right down and looping up and going into the center port on the spool valve. The two items not so easy to recognize are the two exhaust ports on the spool valve, which are the two ports farthest away. You can see a hose go out and duck underneath another hose, and a hose go out just right above the grille on the car, come out of the spool valve and duck underneath, and you can actually see the fitting where the two hoses T together, and then that hose from there takes the exhaust air from #3 spool valve after being used in #3 cylinder, takes that exhaust air, and the hose goes from that T, down and through a check valve and into a re-use air tank, which goes across from wheel well to wheel well, and it's made out of 4" square welded steel tubing. Now the exhaust tank that goes underneath the engine is larger than the engine motor frames. The engine motor frames are 3" square welded steel tubing, and the re-use tank that takes the air from the 3" bore cylinder on the right hand engine, that exhaust air from the 3" bore cylinder after it's used in the #3 cylinder, it goes via the manifold and down from the manifold into a hose, and down through a check valve and into that re-use tank stretching from wheel well to wheel well. It is larger because we've had an increase in volume in the air, a decrease in pressure, but we still have to have an easy flow and an abundance of cubic feet of compressed air, even though it's at a lower pressure, and we need to have it available to use in #4 cylinder.

So then from that tank we have a hose coming up, and supplying pressurized air to the spool valve on top of #4 cylinder, and if you'll look at the drawing we have, drawing #3, you'll be able to see the #4 cylinder there, and the spool valve sitting on top of #4 cylinder you can only see three ports, and the other two ports which are the exhaust ports point away from us in this drawing. We simply have two hoses tied hoses tied to the fittings that screw into this spool valve, and go down and into the tailpipe and back to the back of the car like a conventional tailpipe, except the air is cold coming out of this cylinder, because of the decrease in pressure.



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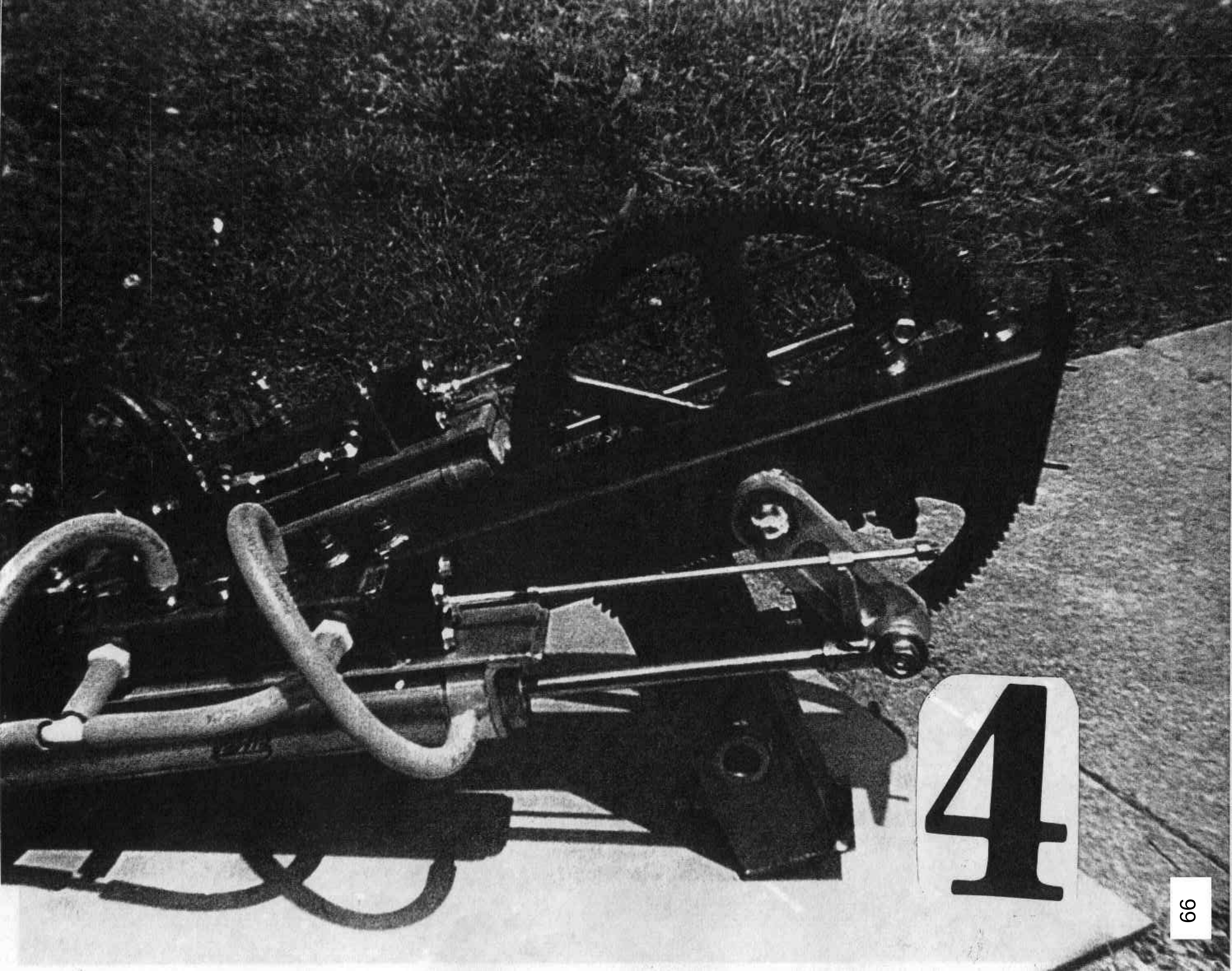
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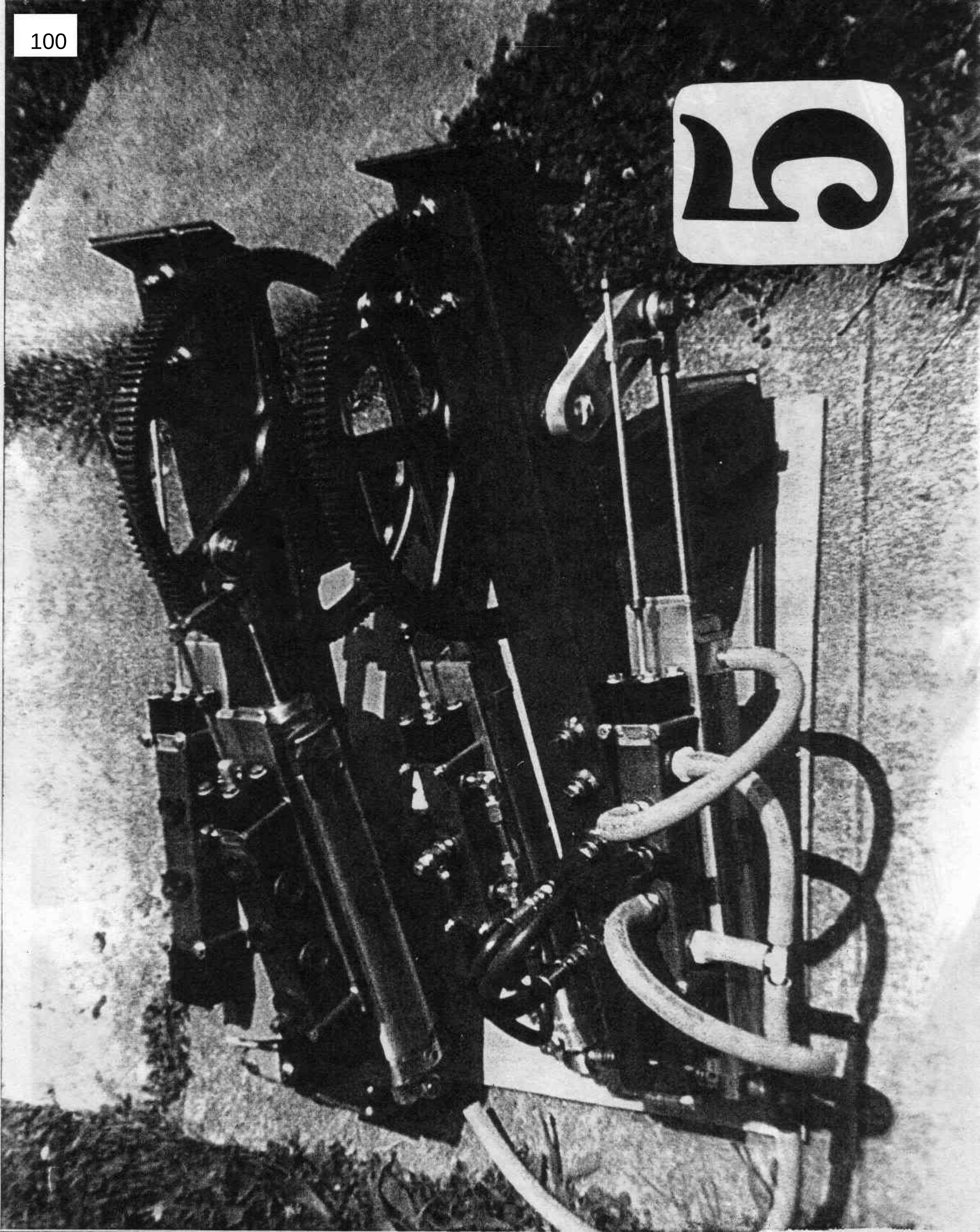
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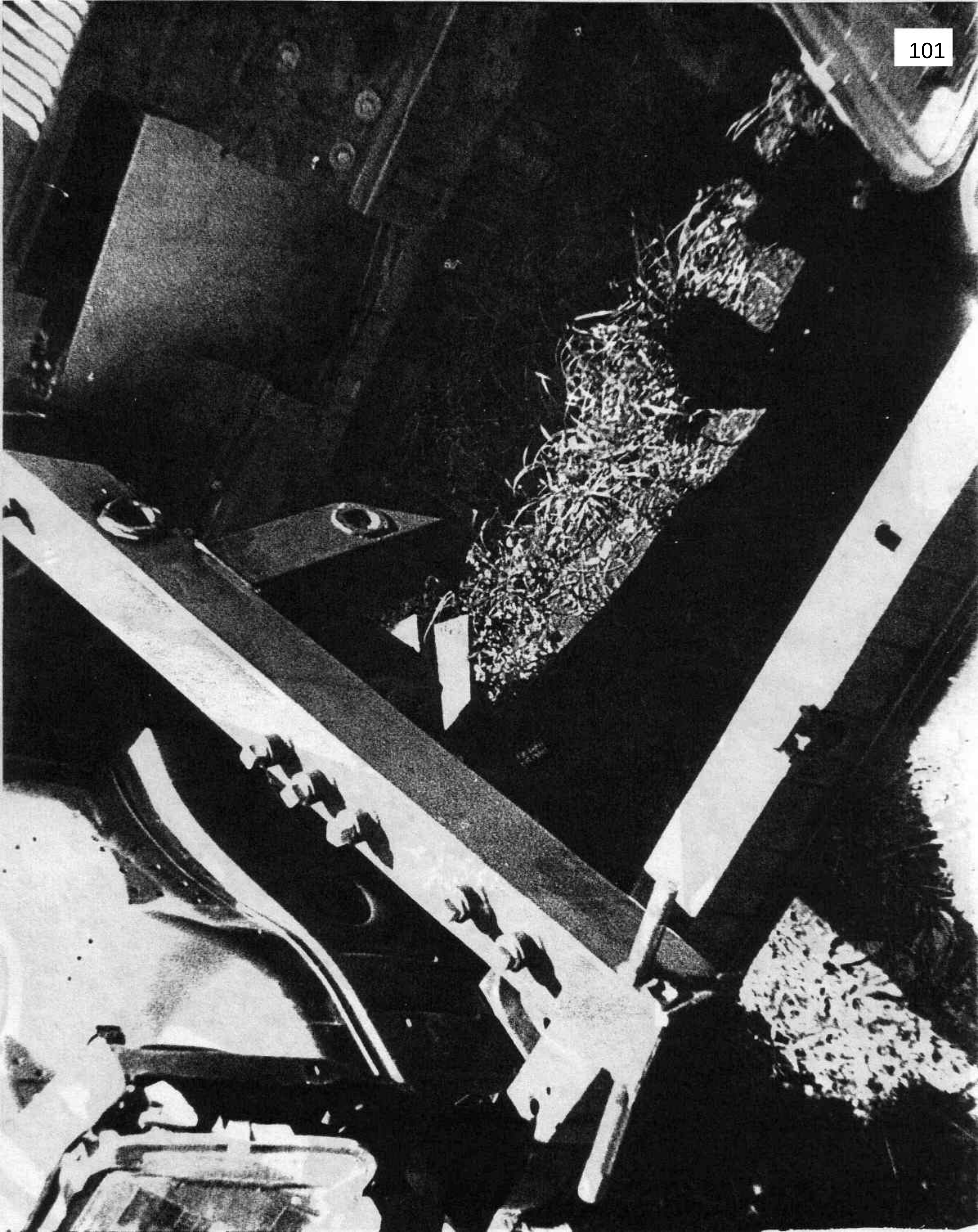
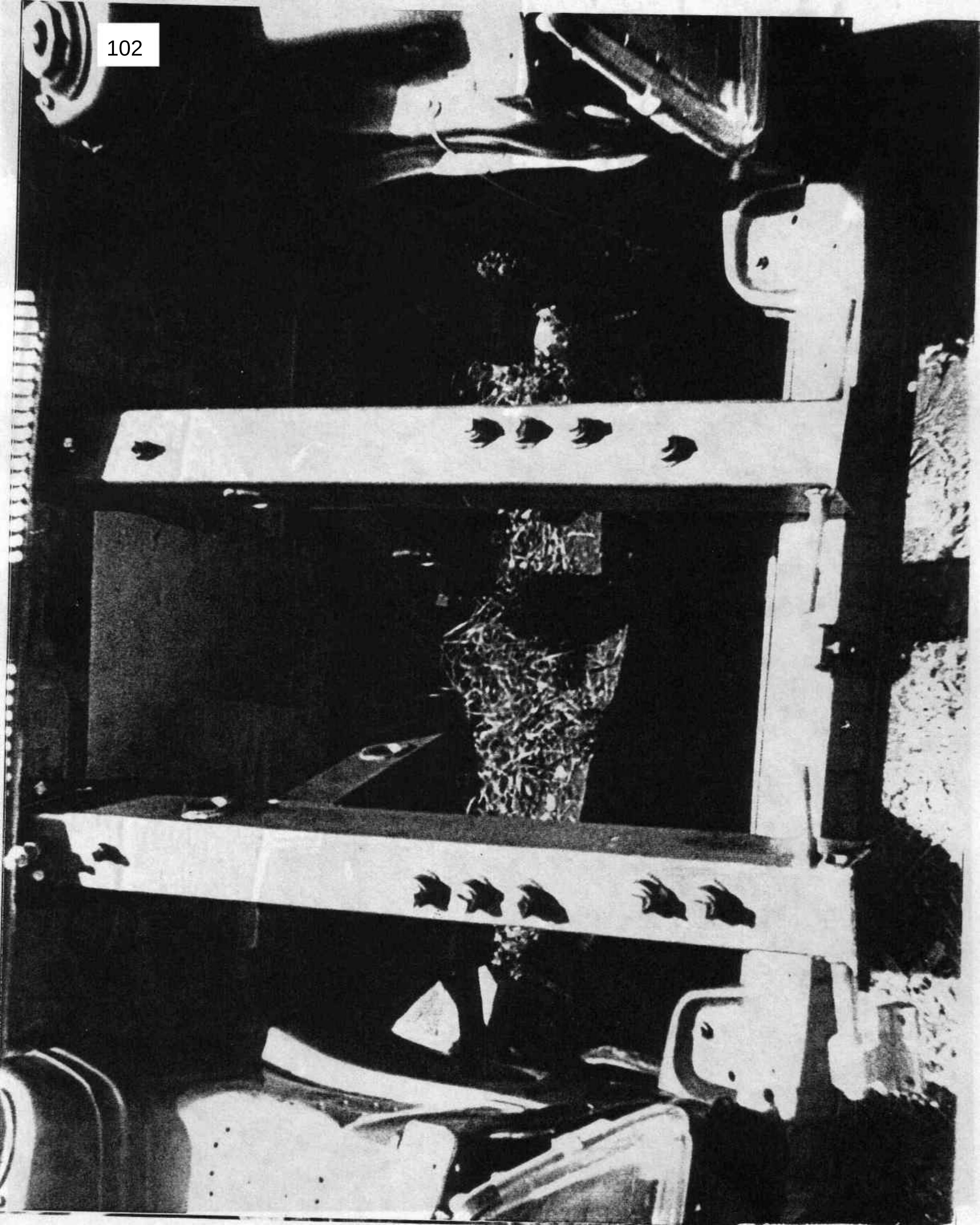
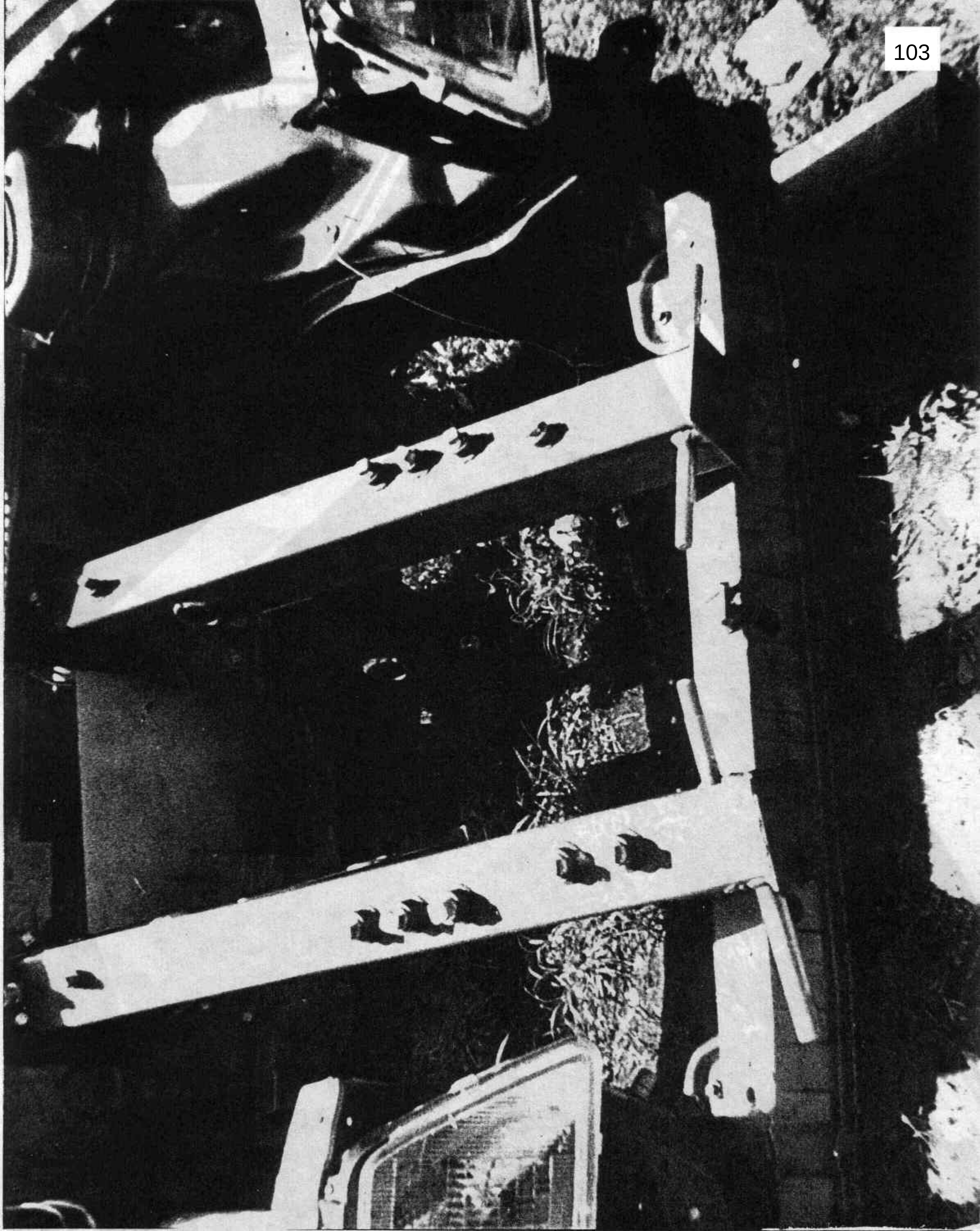
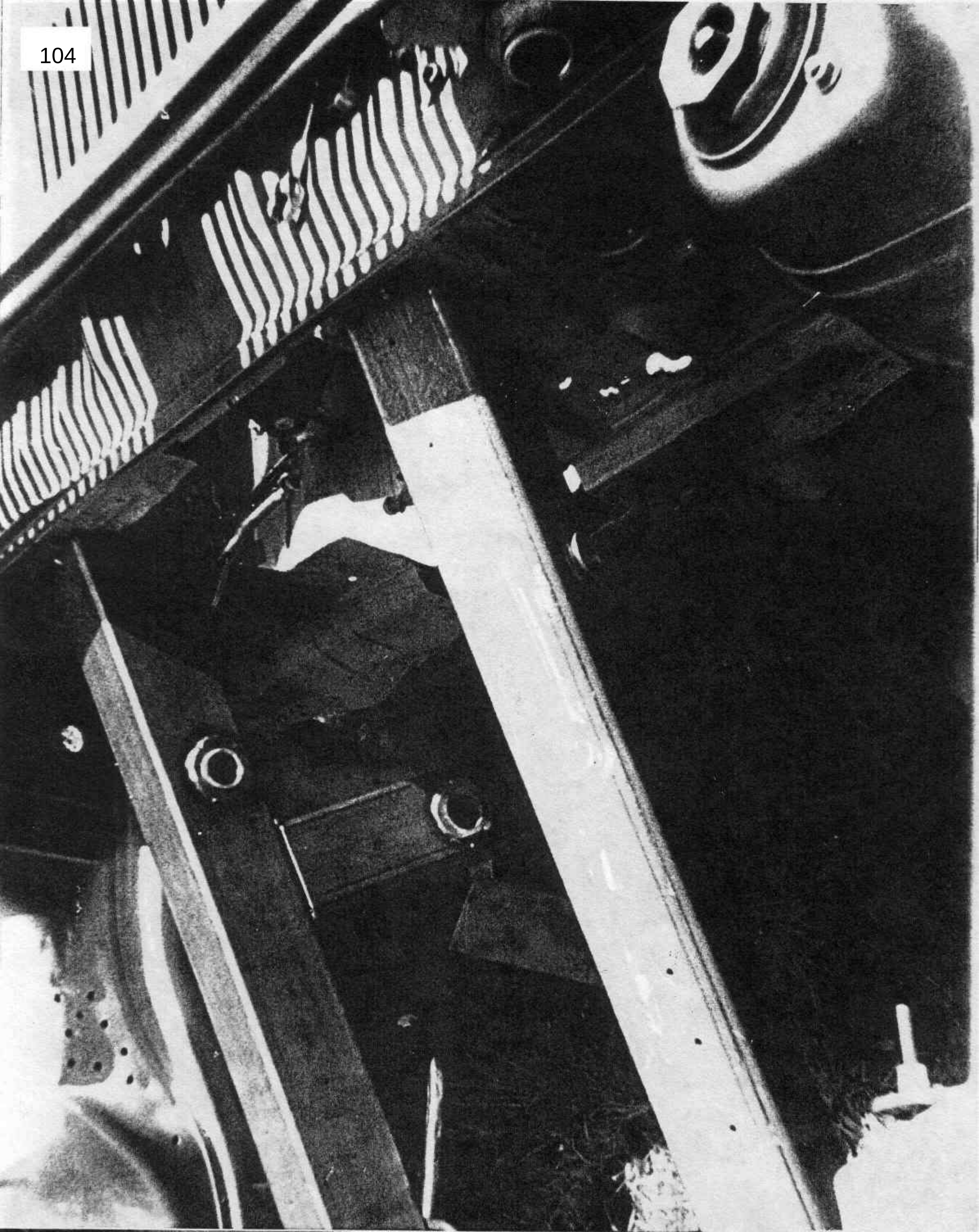
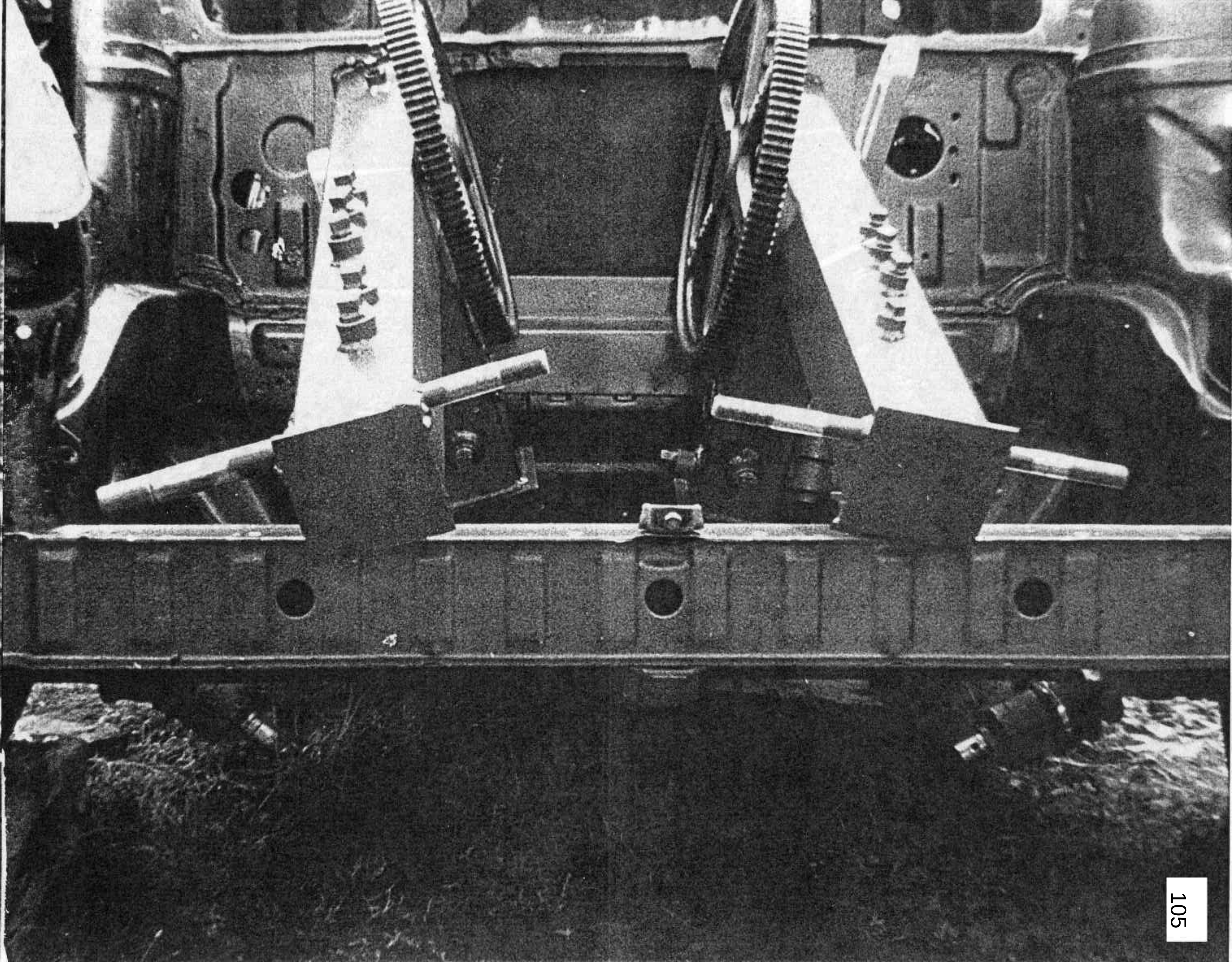
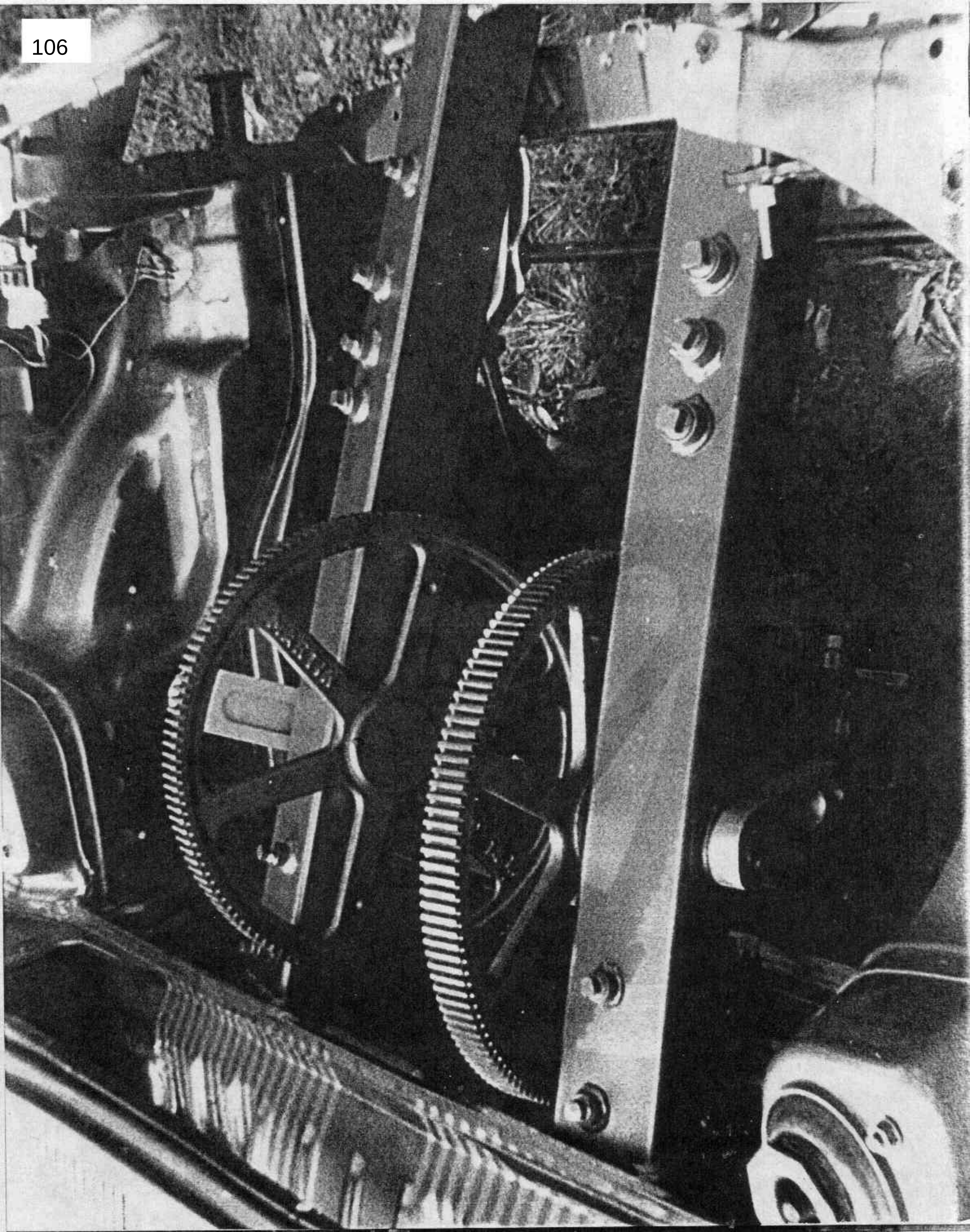


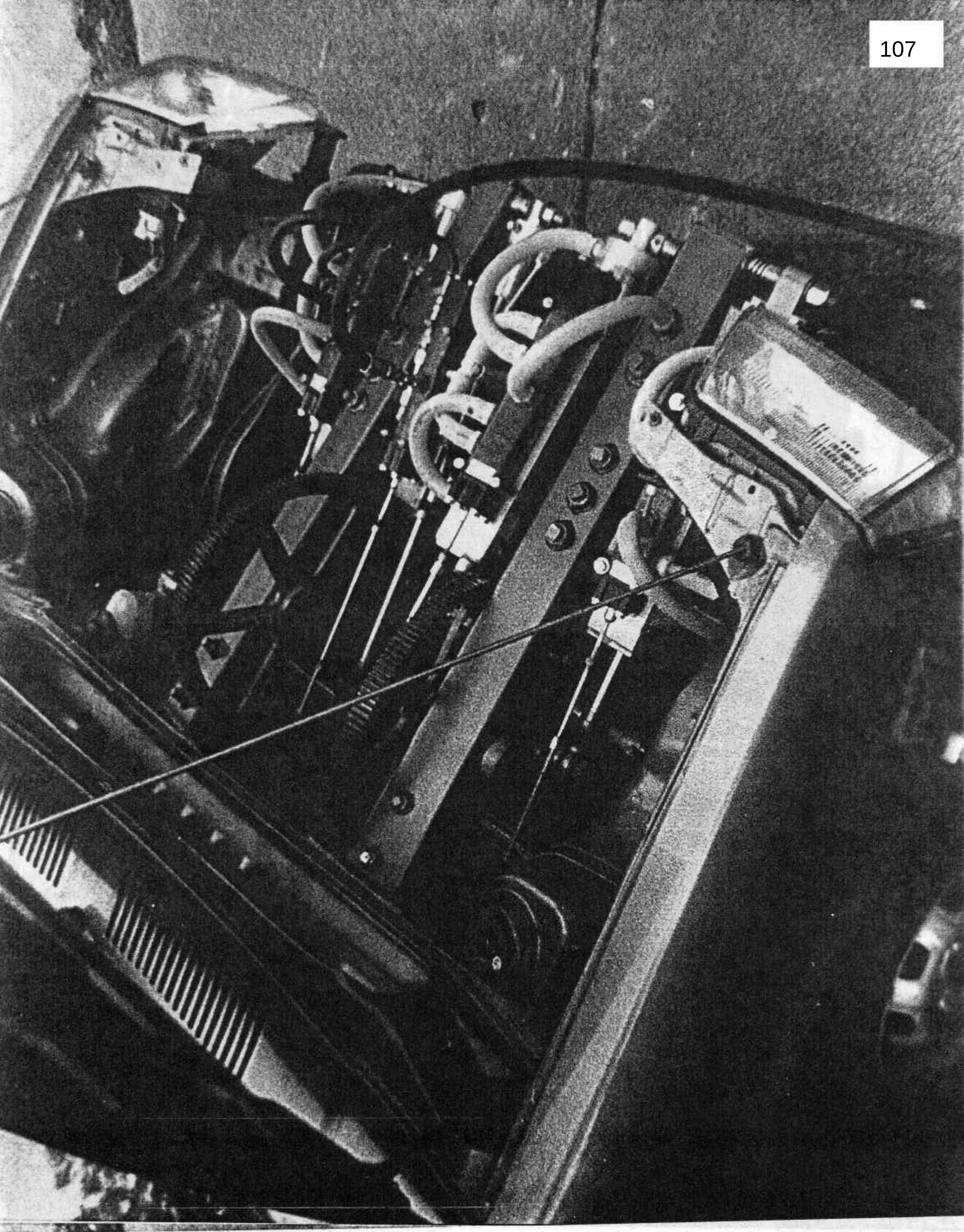


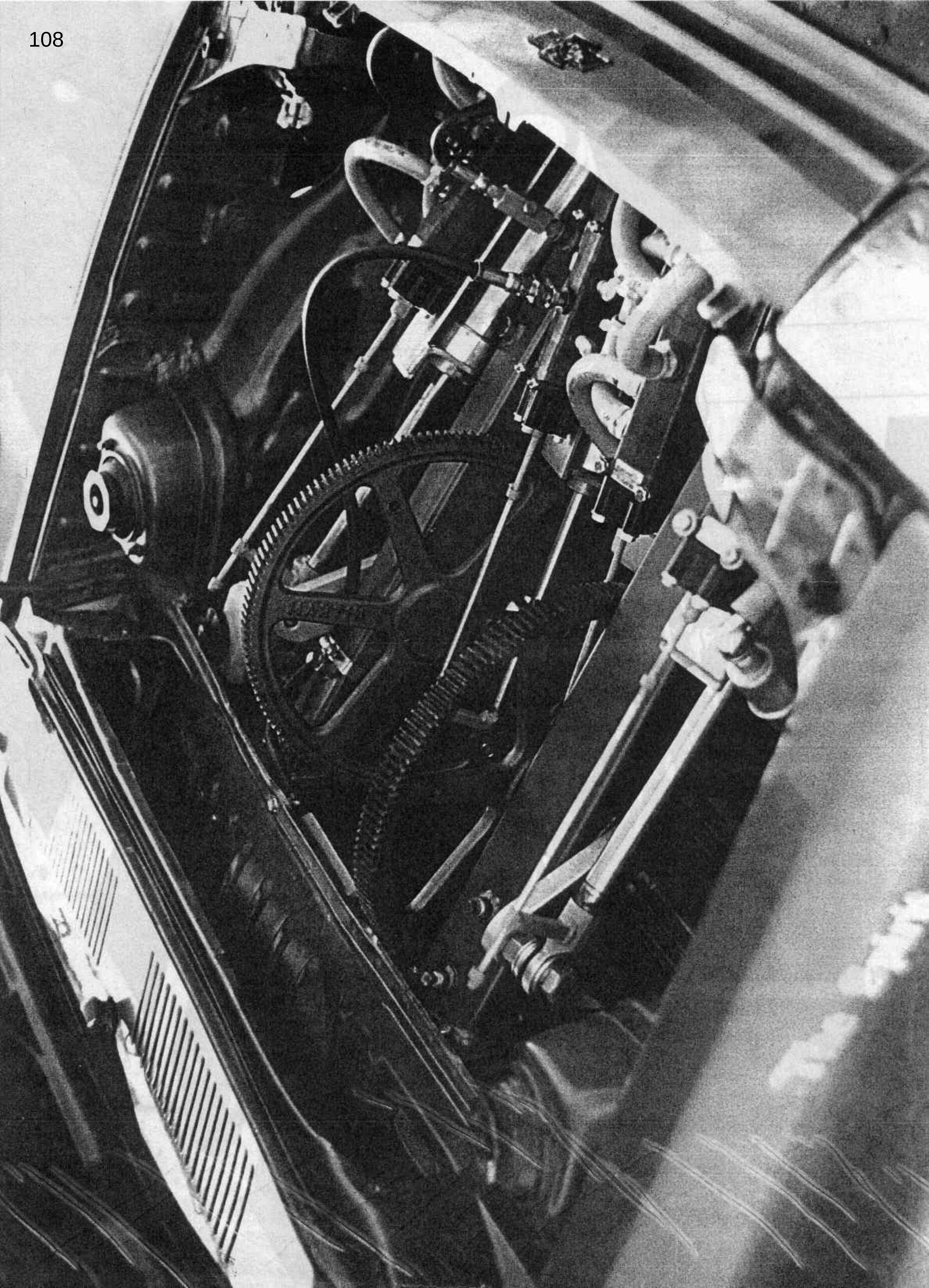


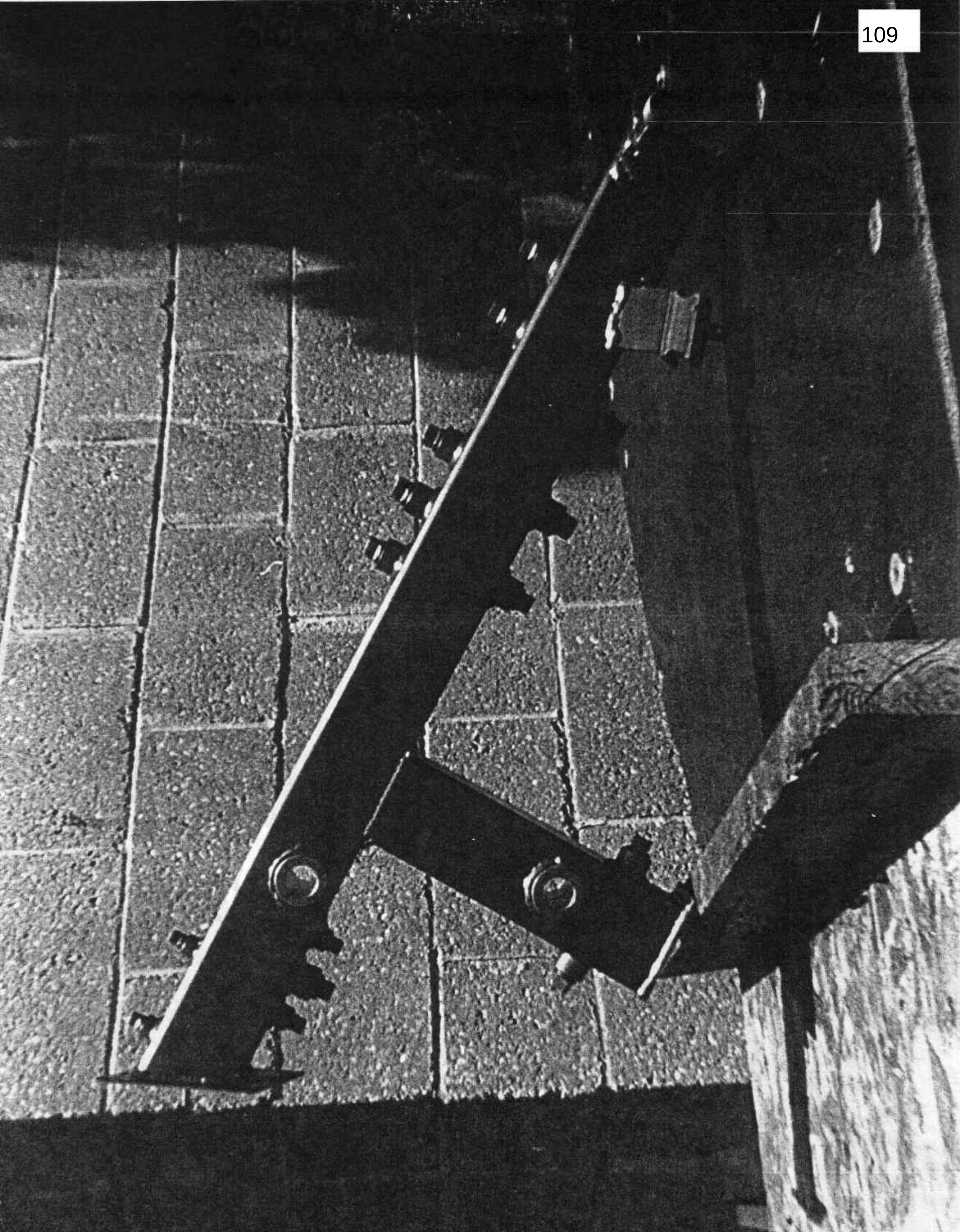


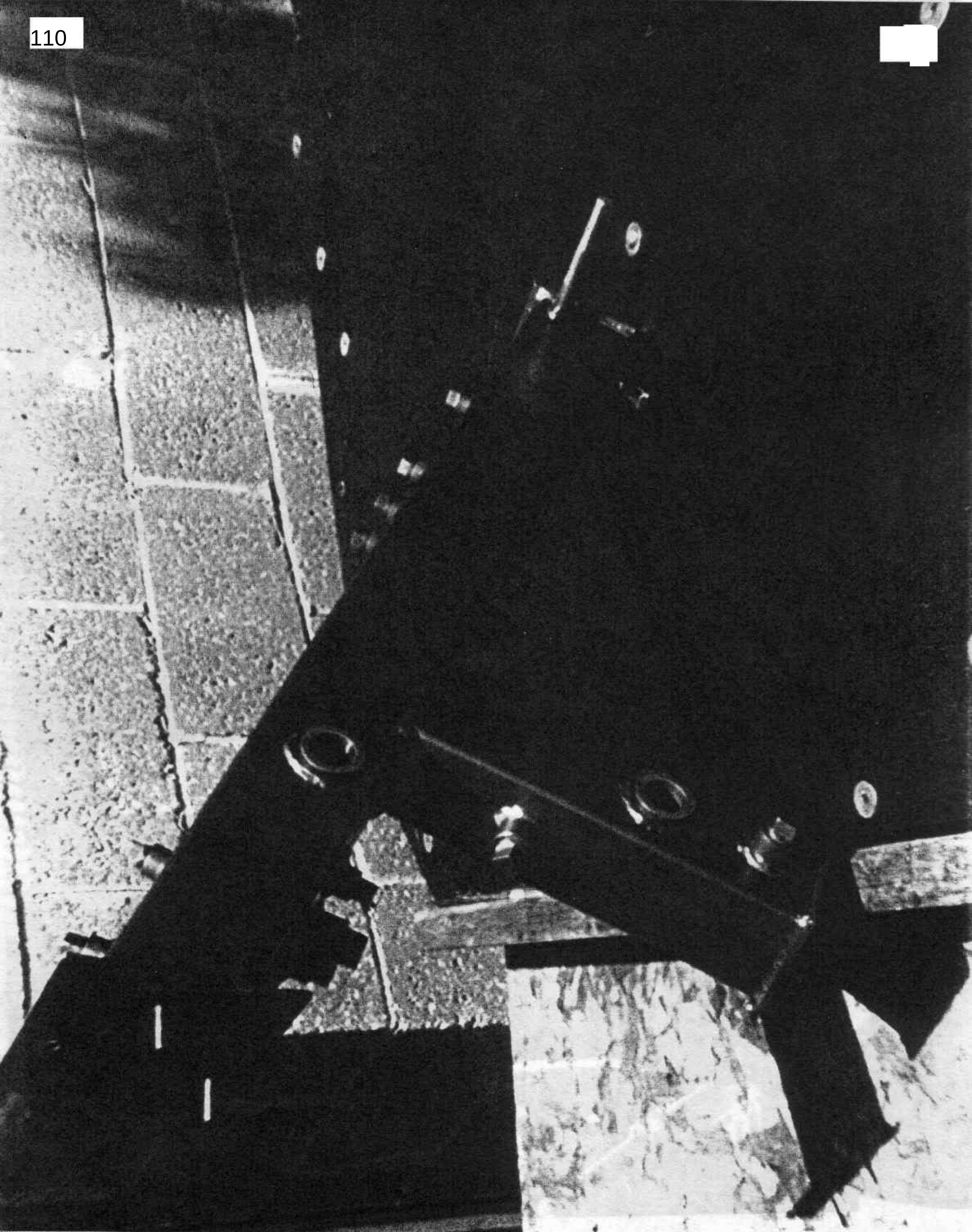


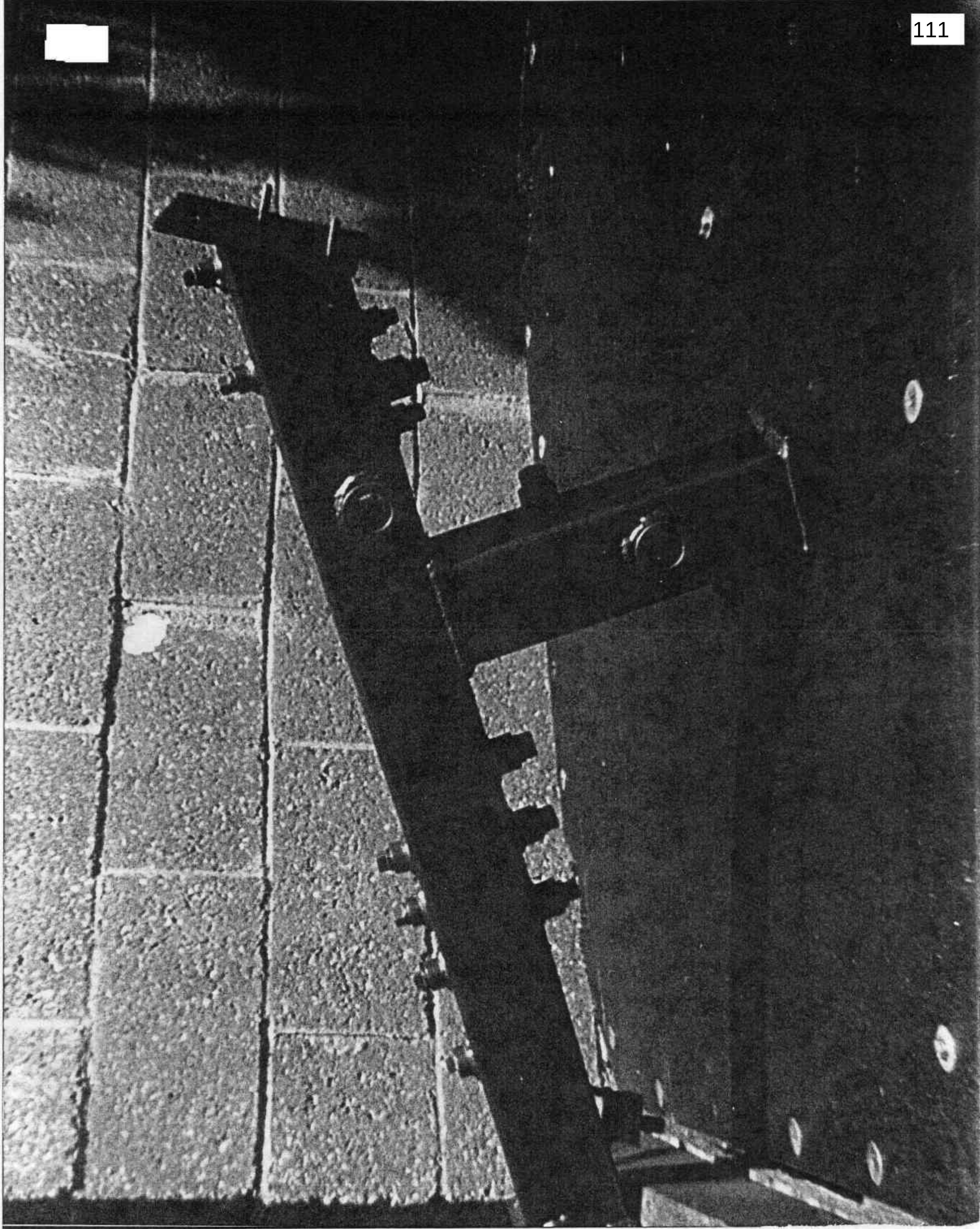


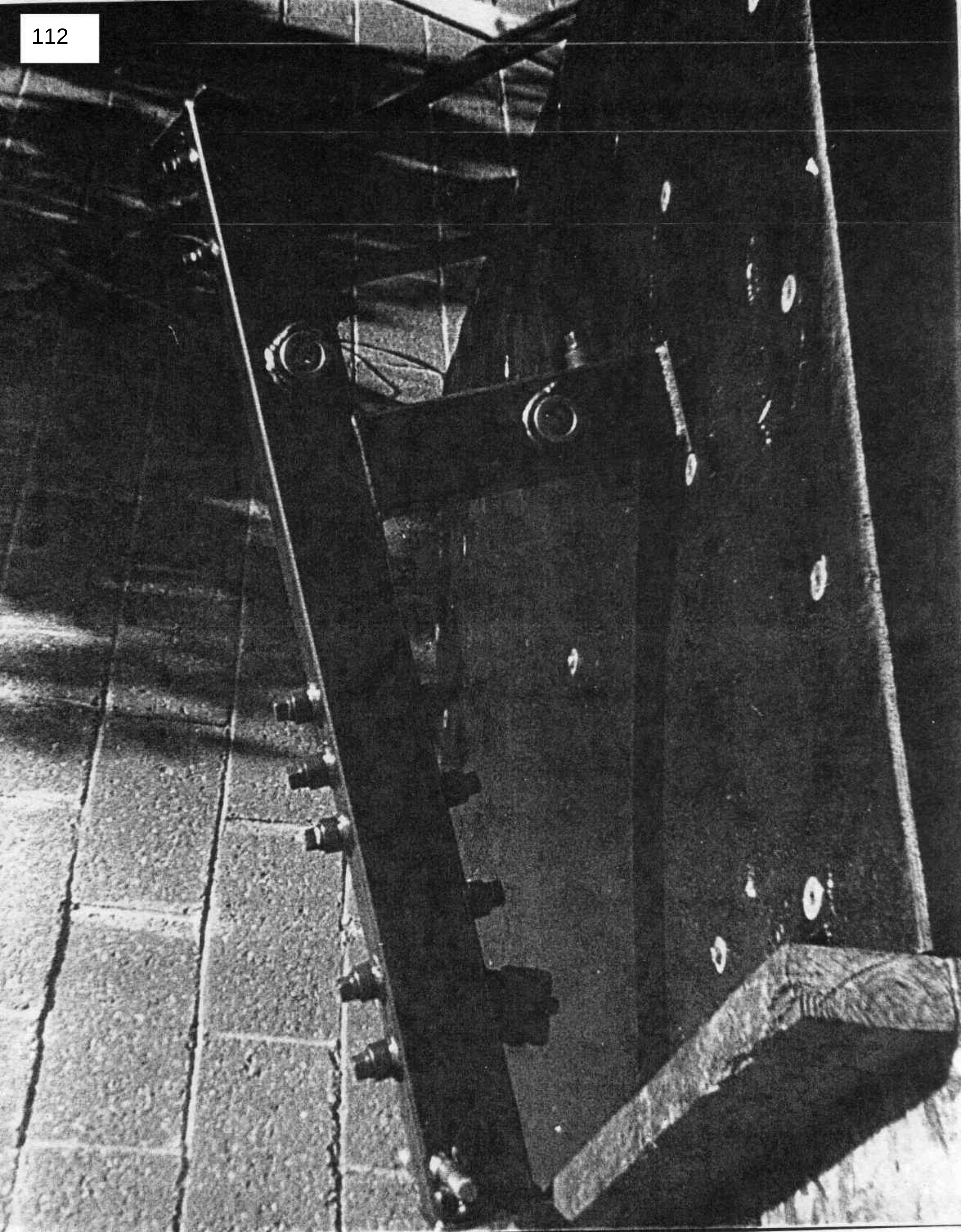


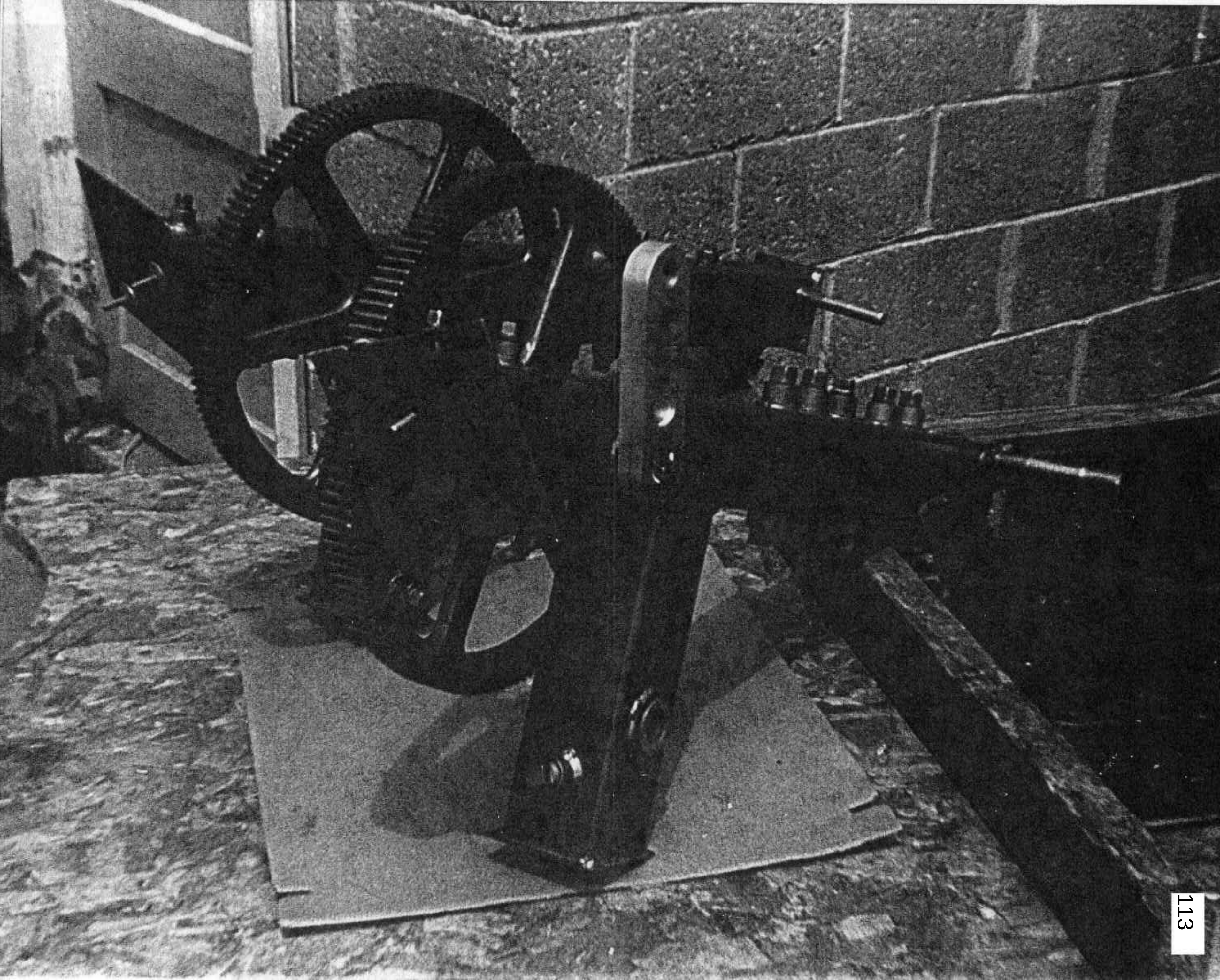


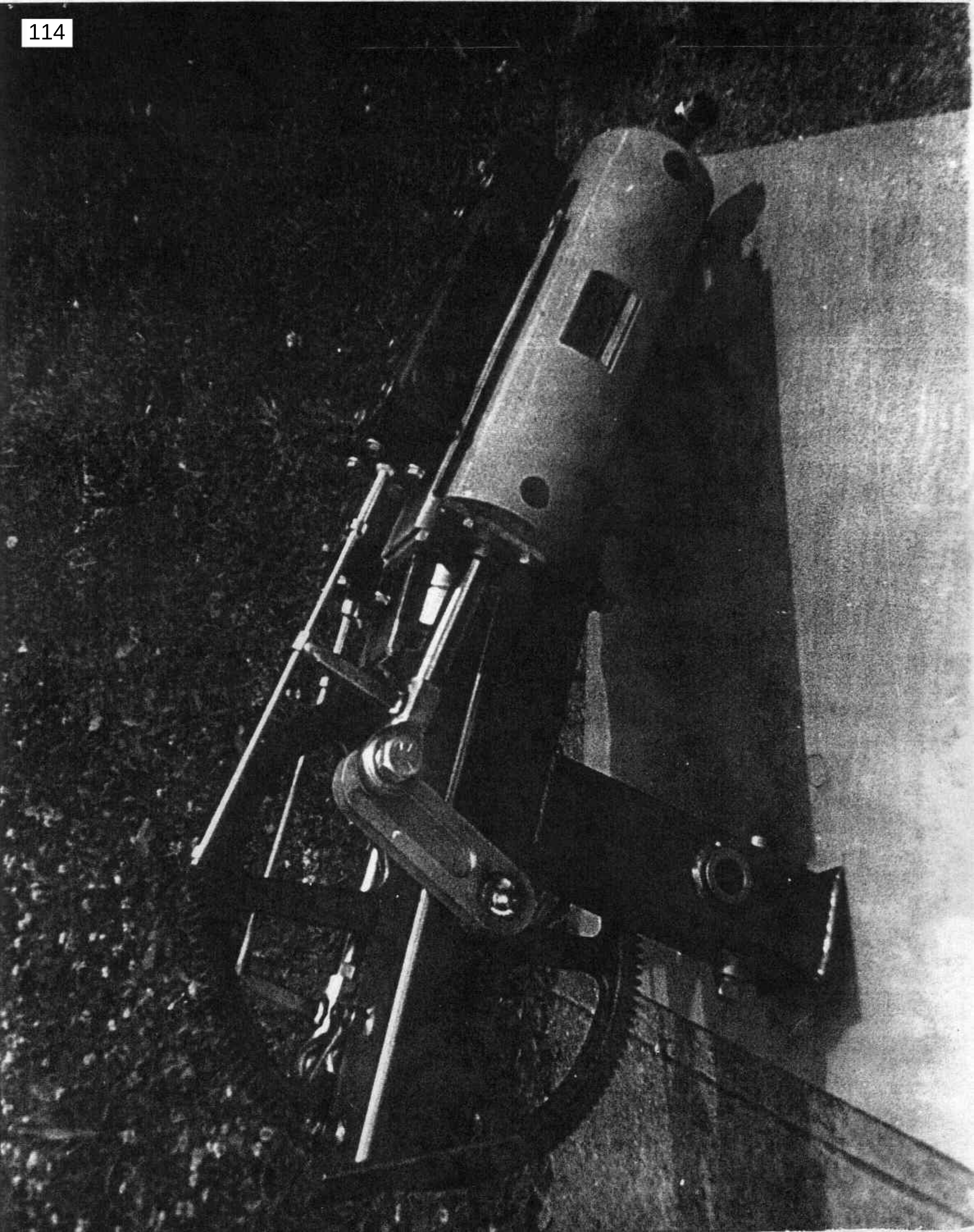


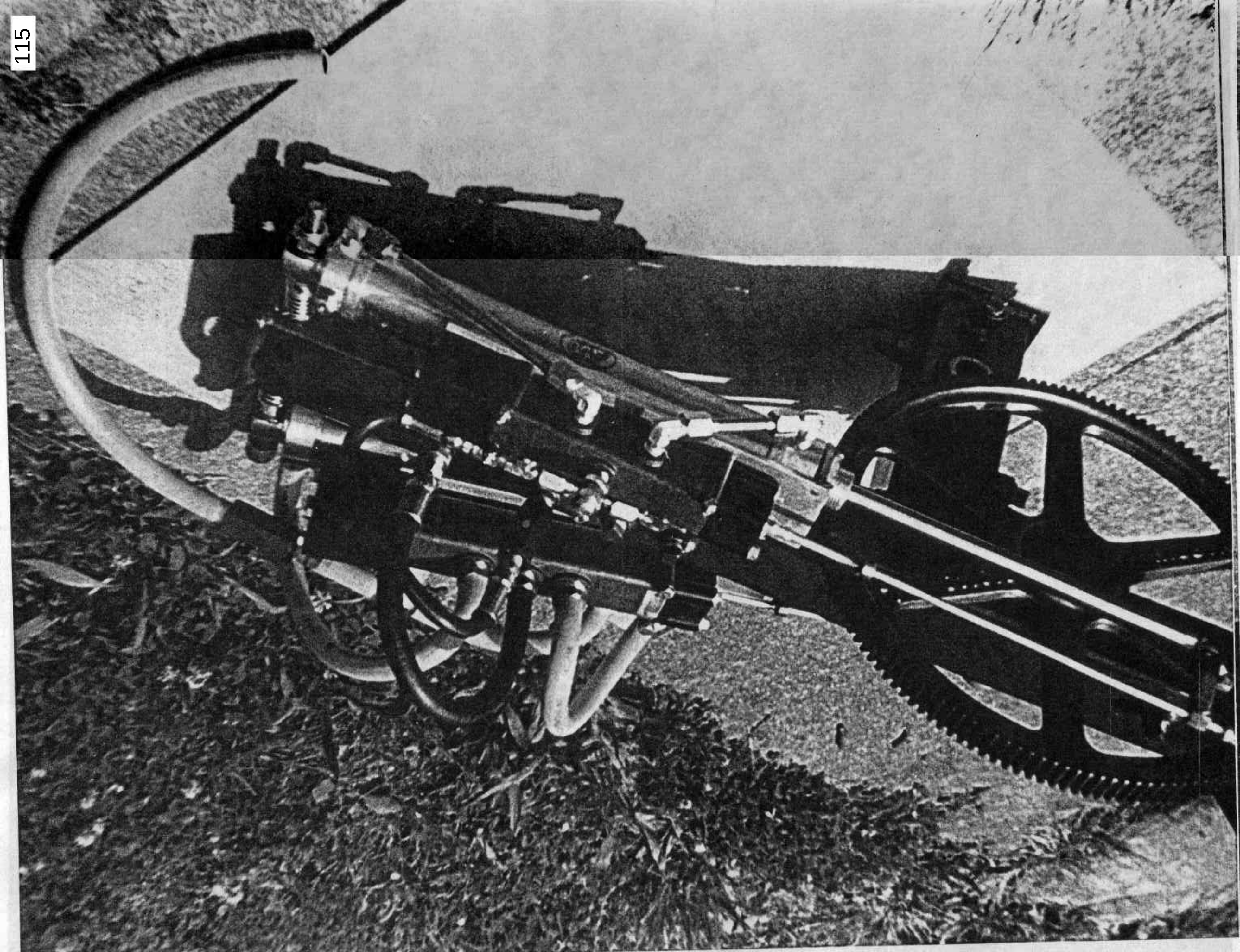


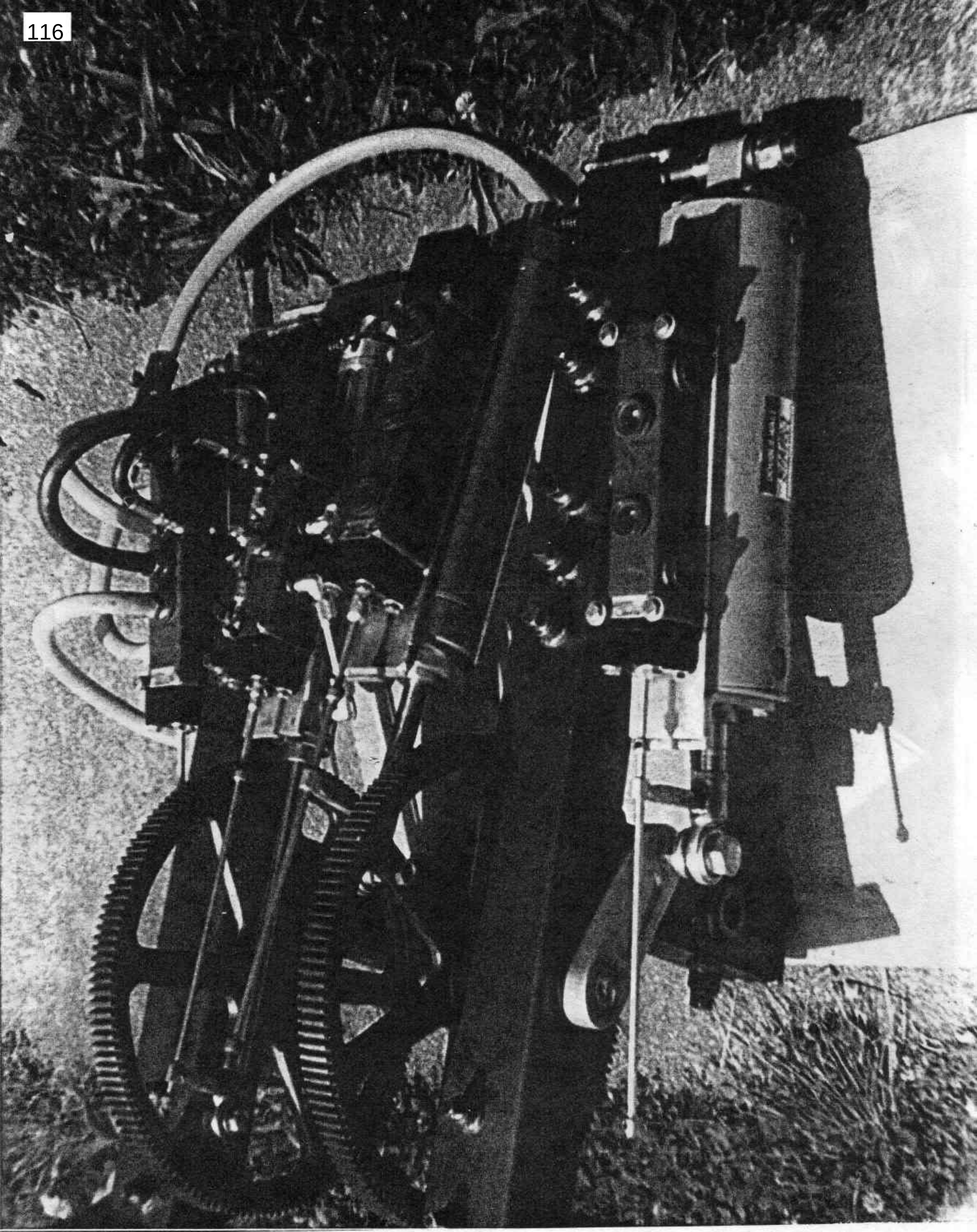


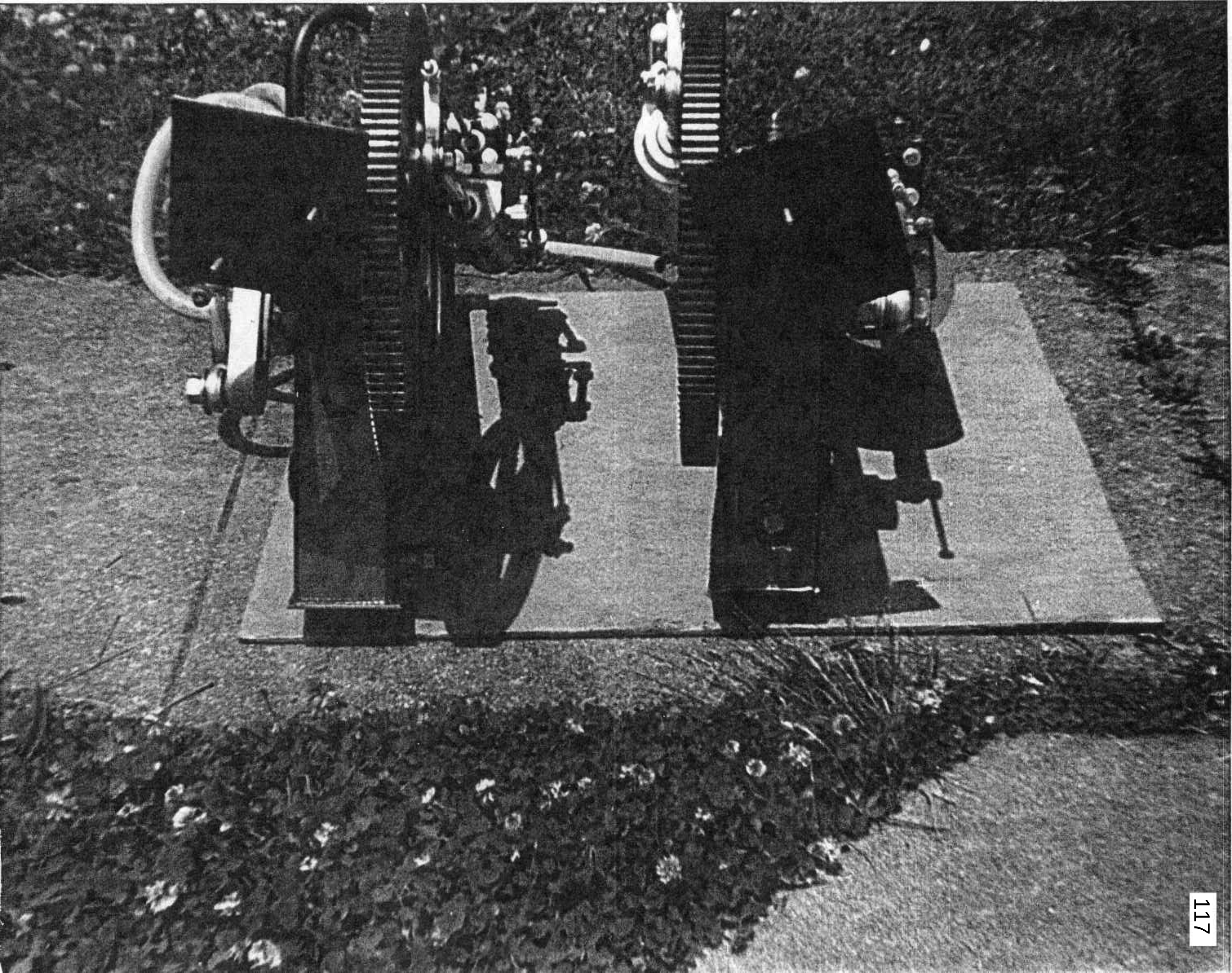


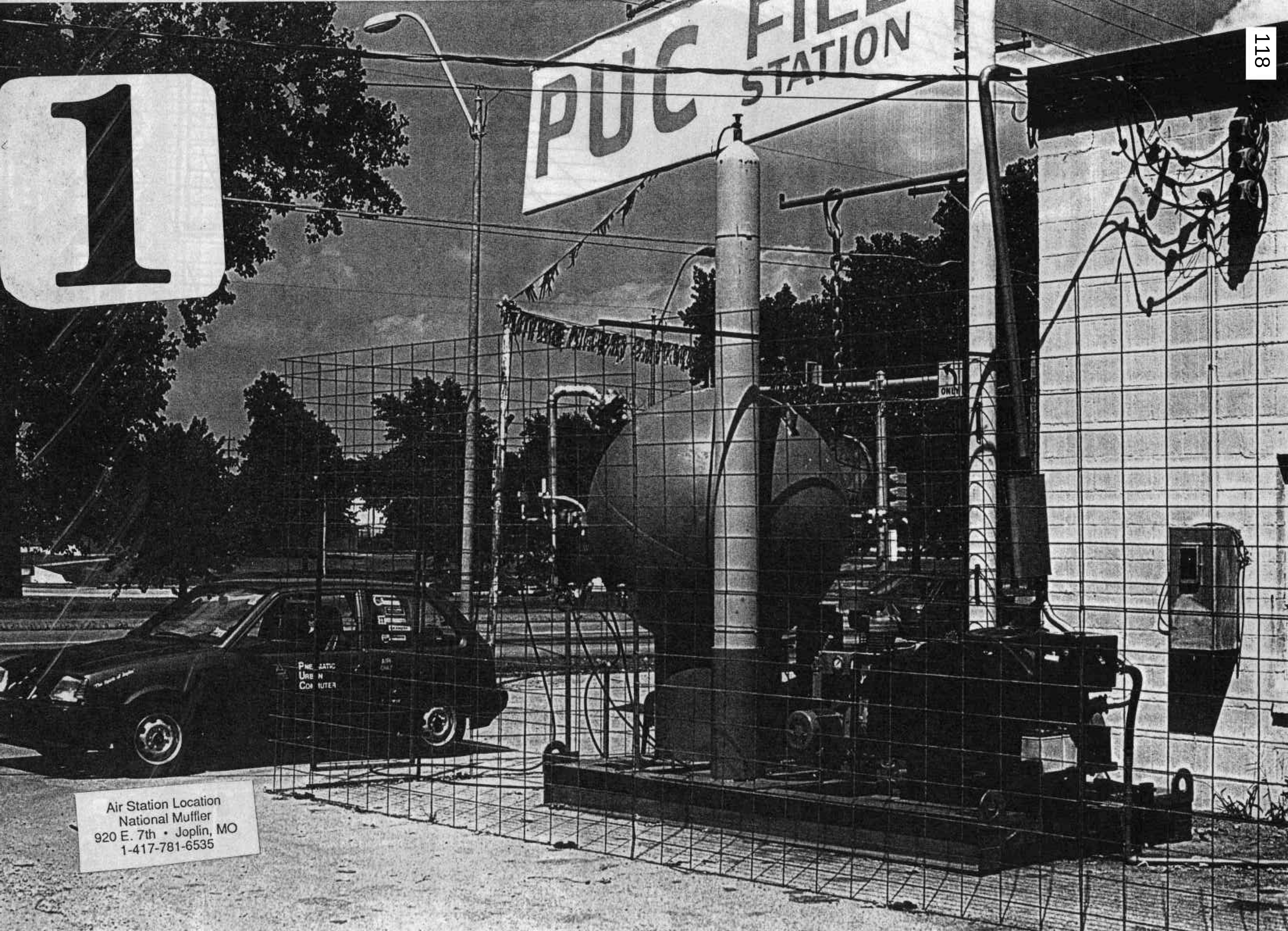






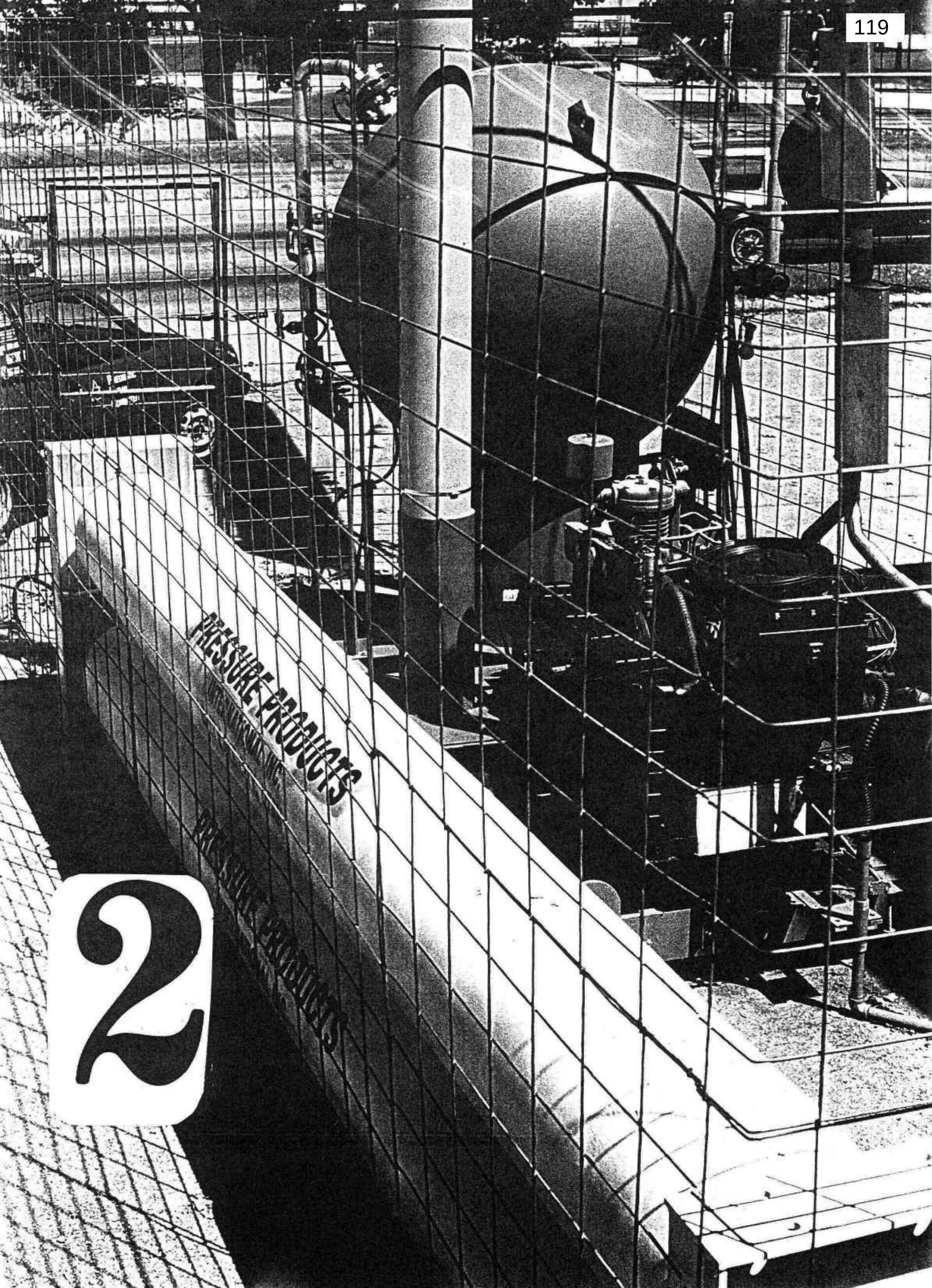


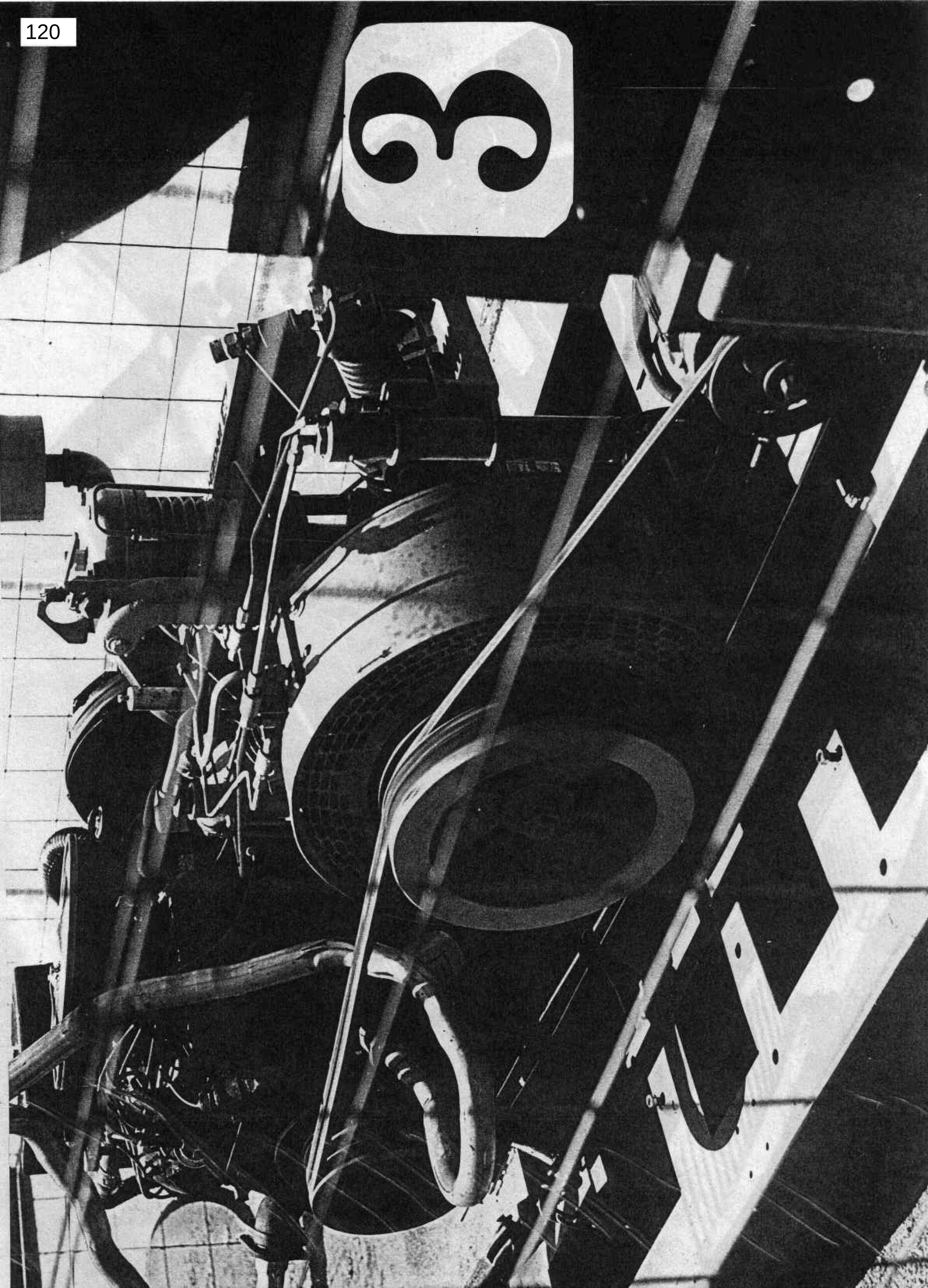




Air Station Location
National Muffler
920 E. 7th • Joplin, MO
1-417-781-6535

2

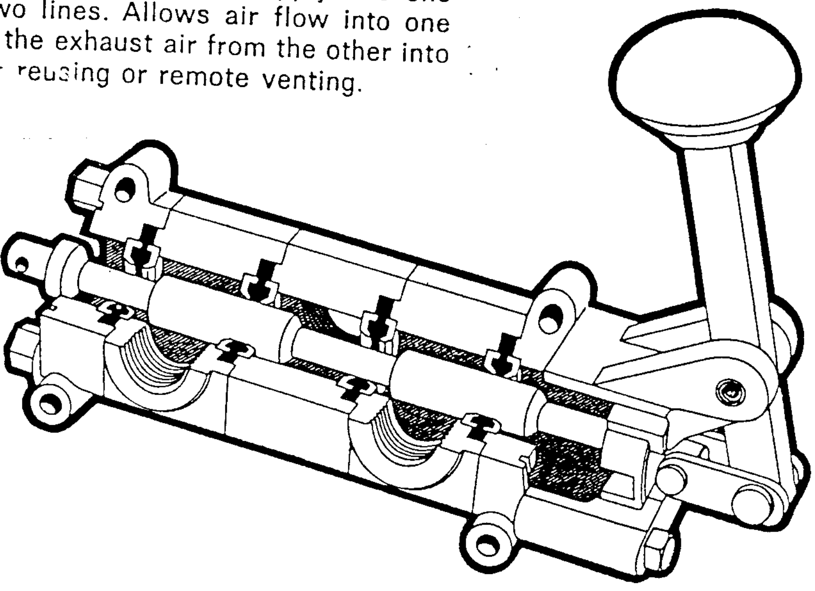



3

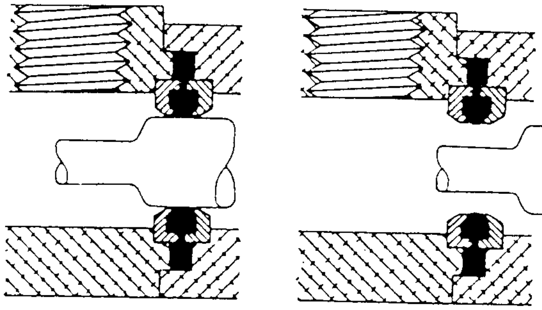
REXROTH TYPE "D" PILOTAIR® VALVES

PD2 = ¼" Valve
PD4 = ½" Valve

To control air flow from a common supply into one or the other of two lines. Allows air flow into one line while venting the exhaust air from the other into a separate line for reusing or remote venting.



POSITIVE SEALING — A unique seal design made from an oil-resistant material developed in the REXROTH laboratories gives the Type "D" PILOTAIR Valve long service life with minimum maintenance at high operating pressures. In the presence of lubrication oil, this material swells minutely to compensate for seal wear.



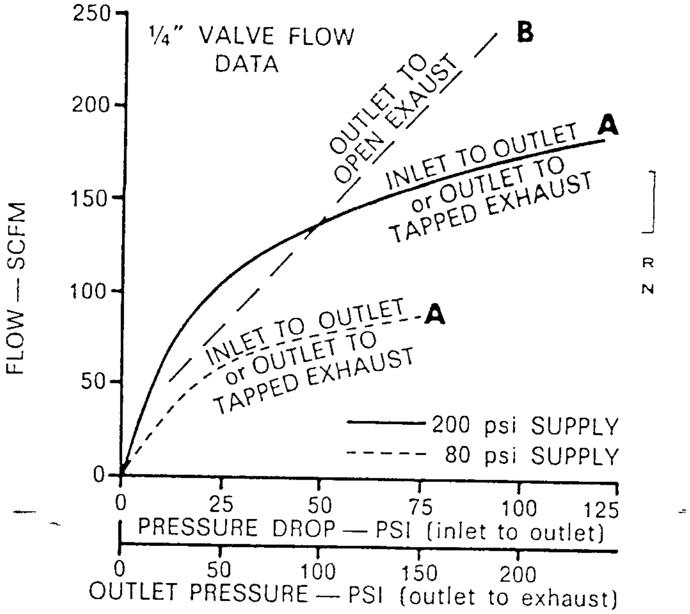
Triple support construction gives an interference fit between the spool and seal to provide sealing effectiveness beyond that of conventional O-ring sealed valves. This same construction ensures that the seals remain in position and are protected from damage by the moving spool.

VERSATILE — There is no standard assembly of the Type "D" PILOTAIR Valve. The directional valve you need is easily tailored to your installation - at standard model prices. Any of nine basic valves may be operated by one or two of eight basic operators. The Type "D" PILOTAIR Valve may have an operator on either or both ends. Various operator spring return and holding functions are available. The valve operators, mounting bracket or any of the port segments may be rotated in 90 degree increments to fit most any installation problem.

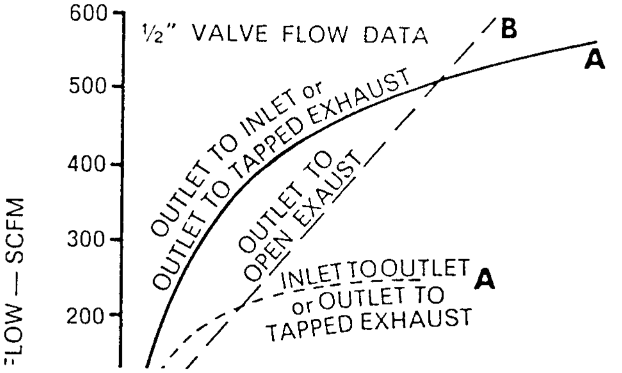
Most valves are made from common parts to simplify repair and stocking. No special tools are required to service or modify Type "D" PILOTAIR Valves.

The Type "D" PILOTAIR Valve can be used for functions other than directional control (see "Pilot Cylinder Operator" and "Low Pressure Pilot Cylinder" on pages 35 and 36).

CAPACITY — As shown by the charts, the Type "D" PILOTAIR Valve is designed to provide maximum capacity flow to speed operations and to provide full power.



"A" FLOW FACTOR = .83 $C_v = 1.47$
"B" FLOW FACTOR = 1.2 $C_v = 2.12$

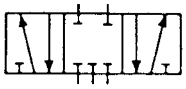


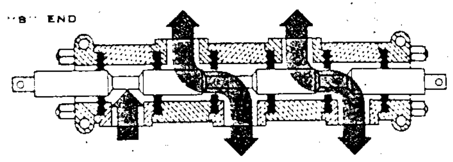
REXROTH TYPE "D" PILOTAIR® VALVES

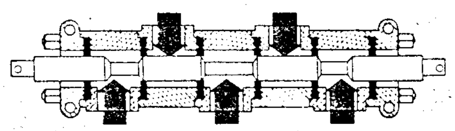
FOUR WAY VALVES — TAPPED EXHAUST — CLOSED CENTER
COMPLETE ASSEMBLY PIECE NUMBERS

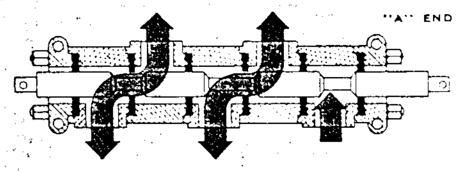
PD2 = 1/4" Valve
PD4 = 1/2" Valve

CLOSED CENTER POSITION









SINGLE OPERATOR

OPERATOR	OPERATOR WITH					
	NO SPRING RETURN			FULL SPRING RETURN		CENTERING SPRINGS
	No End Cover	With End Cover	With Detent †	No End Cover	With End Cover	
Lever	PD2-42-0100 PD4-42-0100	PD2-42-0198 PD4-42-0198	PD2-42-0191 PD4-42-0191	PD2-42-0002 PD4-42-0002	PD2-42-9802 PD4-42-9802	PD2-42-0354 PD4-42-0354
Button	PD2-42-0400 PD4-42-0400	PD2-42-0498 PD4-42-0498	PD2-42-0491 PD4-42-0491	PD2-42-0500 PD4-42-0500	PD2-42-0598 PD4-42-0598	PD2-42-0654 PD4-42-0654
Button (with flange mounting)	PD2 42 8700 PD4-42-8700	PD2 42 8798 PD4 42 8798	PD2 42 8791 PD4 42-8791	PD2-42 8800 PD4-42-8800	PD2 42 8898 PD4-42-8898	PD2-42-8954 PD4-42-8954
Cam				PD2-42-0800 PD4-42-0800	PD2-42-0898 PD4-42-0898	
Pilot Cylinder				PD2-42-1100 PD4-42-1100	PD2-42-1198 PD4-42-1198	
Solenoid* (120V.,60C)				PD2-42-1400 PD4-42-1400	PD2-42-1498 PD4-42-1498	
Solenoid* (240V.,60C)				PD2-42 1700 PD4-42-1700	PD2-42-1798 PD4 42-1798	
Foot Pedal				PD2-42-2300 PD4-42-2300	PD2-42-2398 PD4-42-2398	
Foot Treadle	PD2-42-5200 PD4-42-5200	PD2-42-5298 PD4-42-5298				PD2-42-5354 PD4-42-5354
Low Pressure Pilot Cylinder	PD2-42-1900 PD4-42-1900	PD2-42-1998 PD4-42-1998		PD2-42-2000 PD4 42-2000	PD2-42-2098 PD4-42-2098	PD2-42-2154 PD4-42-2154

REXROTH Pneumatics Major Manufacturing Facilities

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Hannover, West Germany
Milano, Italy
Paris, France

Licensees with Manufacturing Facilities

Chippenham, England
Hiroshima, Japan
Kobe, Japan
San Juan Del Rio, Mexico

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Printed in U.S.A.
REV. MARCH 1991

SC-700

A mannesmann technology company

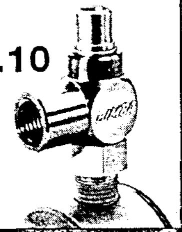
†Three-position detent

2-1/2" BORE AIR CYLINDERS

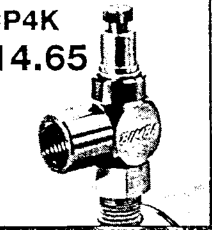
- Ground and Polished, High Strength Carbon Steel Piston Rod Standard – 303 Stainless Steel Rod Available as an Option – Bronze Rod Guide Bushing Standard
- Force Exerted Approx. 5.0 of Air Line Pressure
- Double Acting Only
- Bumpers Available as an Option (See Accessories)
- Mounting Nuts Not Included

☐ Enter Stroke Length as 3rd Digit

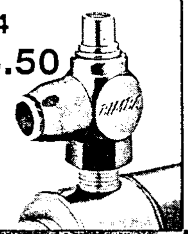
FCP4 **$13.10**



FCP4K **$14.65**

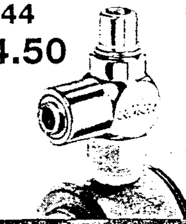


FQP4 **$14.50**

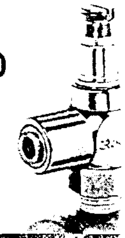


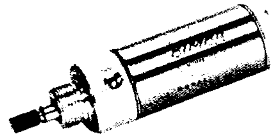
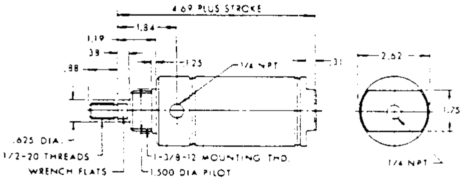
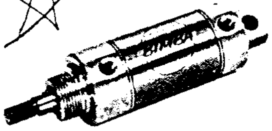
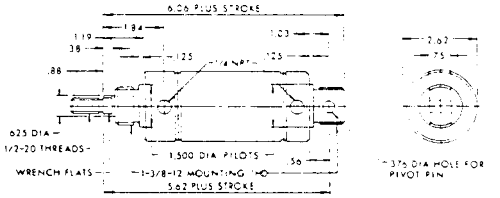
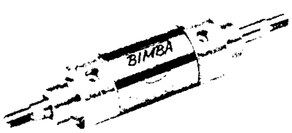
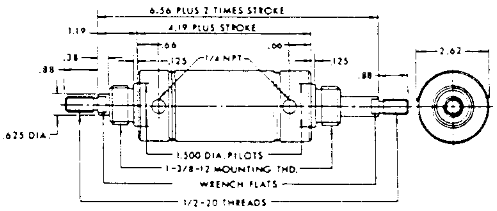
FQP4K **$16.60**

FQP44 **$14.50**



FQP44K **$16.60**



MODEL	DESCRIPTION	PRICE	DIMENSIONS
50☐-D 	**Double Acting**–Air Return–Front Nose Mounting– Standard Stroke Lengths: 1/2", 1", 1 1/2", 2", 2 1/2", 1" increments 3" to 6" Maximum Stroke 12" Stainless Steel Rod Add $2.80 Optional Accessories: D-615-1 Mounting Bracket D-2540 Mounting Nut	**$57.45** BASE PRICE Add $2.30 per inch of stroke	 4.69 PLUS STROKE 1.34 1.19 .38 .125 1/4 NPT .88 .31 2.62 1.75 .625 DIA. 1/2-20 THREADS WRENCH FLATS 1-3/8-12 MOUNTING THD. 1.500 DIA PILOT 1/4 NPT
50☐-DXP 	**Double Acting**–Universal Mounting Type–Pivot or Double End–Air Return–Bronze Rod Bushing and Bronze Pivot Bushing– Standard Stroke Lengths: 1/2", 1", 1 1/2", 2", 2 1/2", 1" increments 3" to 24" Maximum Stroke 32" Stainless Steel Rod Standard Optional Accessories: D-231-3 Piston Rod Clevis D-615-1 Mounting Bracket D-620 Pivot Brackets D-2540 Mounting Nut	**$67.50** BASE PRICE Add $2.40 per inch of stroke	 6.06 PLUS STROKE 1.84 1.19 .38 .125 1/4 NPT 1.03 .125 .88 2.62 .75 .625 DIA 1/2-20 THREADS 1.500 DIA PILOTS .56 WRENCH FLATS 1-3/8-12 MOUNTING THD 5.62 PLUS STROKE .375 DIA HOLE FOR PIVOT PIN
50☐-DXDE 	**Double Acting**–Double End Rod–Air Return–Double End – Mounting– Standard Stroke Lengths: 1/2", 1", 1 1/2", 2", 2 1/2", 1" increments 3" to 12" Maximum Stroke 12" Stainless Steel Rod Standard Optional Accessories: D-615-1 Mounting Bracket D-2540 Mounting Nut	**$78.70** BASE PRICE Add $3.80 per inch of stroke	 6.56 PLUS 2 TIMES STROKE 1.19 4.19 PLUS STROKE .66 .66 .38 .125 1/4 NPT .125 .88 .88 2.62 .625 DIA. 1.500 DIA. PILOTS 1-3/8-12 MOUNTING THD. WRENCH FLATS 1/2-20 THREADS

2-1/2" BORE ACCESSORIES

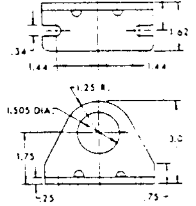
VITON A "U" CUPS

Temperature Range
0 to 400°F
(–18° to 205°C)

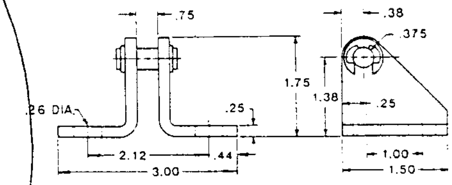
ouble acting models .....Add $14.10
ouble end rod model ....Add $18.70

DOUBLE ACTING BUMPERS

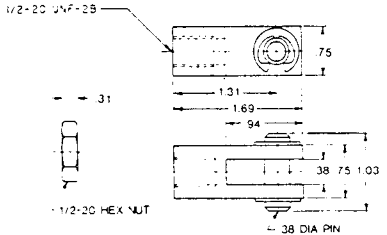
$4.95 additional
Add .250 to overall length



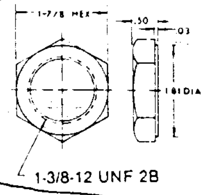
D-615-1
Mounting Bracket
$6.60



D-620
Pivot Brackets
$8.80



D-231-3
Piston Rod Clevis
$4.45



D-2540
Mounting Nut
$3.55

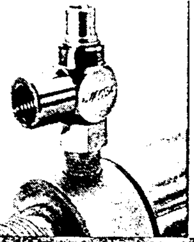
3″ BORE AIR CYLINDERS

☐ Enter Stroke Length as 3rd Digit

- Ground and Polished, High Strength Carbon Steel Piston Rod Standard – 303 Stainless Steel Rod Available as an Option – Bronze Rod Guide Bushing Standard
- Force Exerted Approx. 7.0 of Air Line Pressure
- Double Acting Only
- Mounting Nuts Not Included

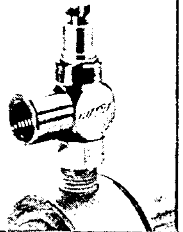
FCP6

$16.35



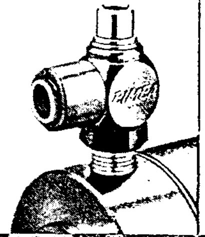
FCP6K

$17.95



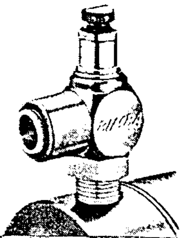
FQP6

$17.95



FQP6K

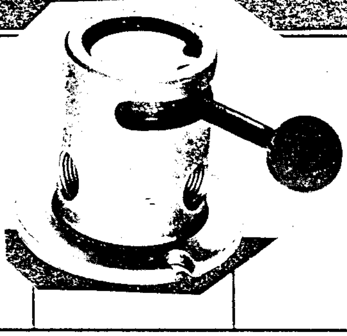
$20.40

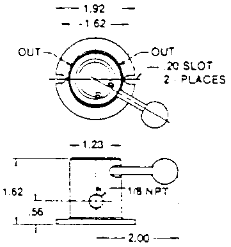


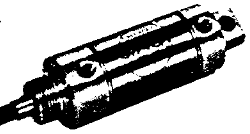
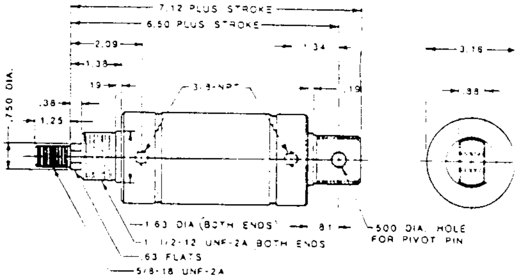
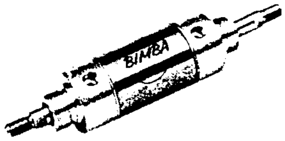
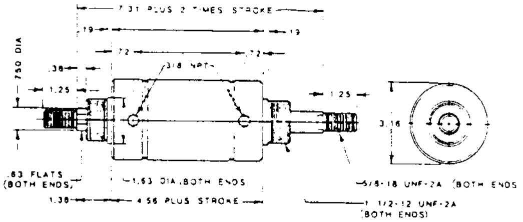
MODEL **DESCRIPTION** **DIMENSIONS**

MODEL 4MV8

4 Way Disc Air Valve operates double acting cylinders. Ball handle will rotate through 120° and will hold set position – 1/8″ NPT ports are located 120° apart – orifice 1/8″ diameter. To repair remove handle and retaining ring.



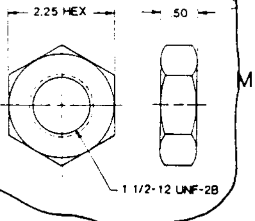


70☐-DXP 	**Double Acting**–Universal Mount Pivot or Double End Mounting– Standard Stroke Lengths: ½", 1", 1½", 2", 2½" 1" increments 3" to 24" Maximum Stroke 32" Stainless Steel Rod Standard Optional Accessories: D-13512-A Pivot Bracket D-19127 Mounting Bracket D-8314-A Rod Clevis D-5379 Mounting Nut	**$92.05** BASE PRICE Add $2.90 per inch of stroke	
70☐-DXDE 	**Double Acting**–Double End Rod–Double End Mounting– Standard Stroke Lengths: ½", 1", 1½", 2", 2½", 1" increments 3" to 12" Maximum Stroke 12" Stainless Steel Rod Standard Optional Accessories: D-19127 Mounting Bracket D-5379 Mounting Nut	**$101.85** BASE PRICE Add $4.00 per inch of stroke	

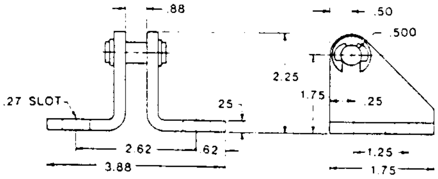
3″ BORE ACCESSORIES

VITON A "U" CUPS
Temperature Range
0 to 400°F
(−18 to 205°C)

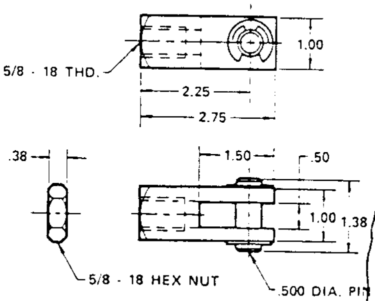
Double acting models
Add **$14.90**
Double end rod model
Add **$19.70**



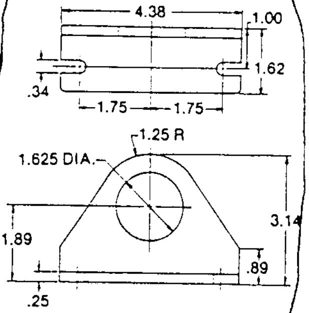
D-5379
Mounting Nut
$3.55



D-13512-A
Pivot Bracket
$9.25



D-8314-A
Rod Clevis
$8.40

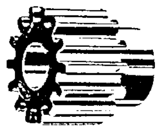


D-19127
Mounting Bracket
$6.95

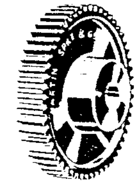
Martin

Cast Iron Stock Spur Gears 10 DP 1" Face

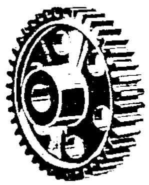
14½° Pressure Angle



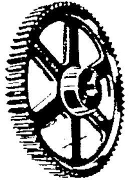
TYPE B
PLAIN WITH HUB



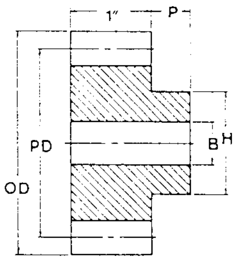
TYPE B₁



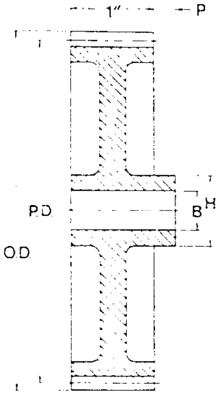
TYPE B₂
WEB WITH LIGHTEN HOLES



TYPE B₃
WEB WITH SPOKES



TYPE B



TYPE B₁, B₂, B₃

Cast - Style "B"

No. Teeth	Catalog Number	Diameter Pitch	Diameter Outside	Type	Bore (Inches) Stock	Bore (Inches) Max.*	Hub (Inches) Dia.	Hub (Inches) Proj.	Weight Lbs. (App.)
• 28	C1028 14½	2.800	3.000	B	3/4	15/16	1 3/4	7/8	1.9
• 30	C1030 14½	3.000	3.200	B	3/4	15/16	1 3/4	7/8	2.1
• 32	C1032 14½	3.200	3.400	B₁	3/4	15/16	1 3/4	7/8	2.3
• 36	C1036 14½	3.600	3.800	B₁	3/4	1 3/16	2 1/8	7/8	2.8
• 42	C1042 14½	4.200	4.400	B₁	7/8	1 3/16	2 1/8	7/8	3.4
• 45	C1045 14½	4.500	4.700	B₁	7/8	1 3/16	2 1/8	7/8	3.5
• 48	C1048 14½	4.800	5.000	B₁	7/8	1 3/16	2 1/8	7/8	3.8
• 50	C1050 14½	5.000	5.200	B₁	7/8	1 3/16	2 1/8	7/8	4.3
• 55	C1055 14½	5.500	5.700	B₁	7/8	1 3/16	2 1/8	7/8	4.5
• 60	C1060 14½	6.000	6.200	B₃	7/8	1 3/16	2 1/8	7/8	4.3
64	C1064 14½	6.400	6.600	B₃	7/8	1 7/16	2 1/2	7/8	5.6
65	C1065 14½	6.500	6.700	B₃	7/8	1 7/16	2 1/2	7/8	5.6
70	C1070 14½	7.000	7.200	B₃	7/8	1 7/16	2 1/2	7/8	5.9
72	C1072 14½	7.200	7.400	B₃	7/8	1 7/16	2 7/8	7/8	6.3
75	C1075 14½	7.500	7.700	B₃	7/8	1 7/16	2 1/2	7/8	6.7
80	C1080 14½	8.000	8.200	B₃	7/8	1 7/16	2 1/2	7/8	7.0
84	C1084 14½	8.400	8.600	B₃	7/8	1 7/16	2 1/2	7/8	6.9
85	C1085 14½	8.500	8.700	B₃	7/8	1 7/16	2 1/2	7/8	7.3
90	C1090 14½	9.000	9.200	B₃	7/8	1 7/16	2 1/2	7/8	7.6
95	C1095 14½	9.500	9.700	B₃	7/8	1 7/16	2 1/2	7/8	8.1
96	C1096 14½	9.600	9.800	B₃	7/8	1 7/16	2 1/2	7/8	8.1
100	C10100 14½	10.000	10.200	B₃	1	1 7/16	2 1/2	7/8	10.3
105	C10105 14½	10.500	10.700	B₃	1	1 7/16	2 1/2	1	10.4
110	C10110 14½	11.000	11.200	B₃	1	1 11/16	2 3/4	1	10.0
112	C10112 14½	11.200	11.400	B₃	1	1 11/16	2 3/4	1	9.0
120	C10120 14½	12.000	12.200	B₃	1	1 11/16	2 3/4	1	10.4
130	C10130 14½	13.000	13.200	B₃	1	1 11/16	2 3/4	1	11.9
140	C10140 14½	14.000	14.200	B₃	1	1 11/16	2 3/4	1	12.9
144	C10144 14½	14.400	14.600	B₃	1	1 11/16	2 3/4	1	12.8
150	C10150 14½	15.000	15.200	B₃	1	1 11/16	2 3/4	1	13.4
160	C10160 14½	16.000	16.200	B₃	1	1 11/16	2 3/4	1	14.4
180	C10180 14½	18.000	18.200	B₃	1	1 13/16	3	1	19.6
• 200	C10200 14½	20.000	20.200	B₃	1	1 13/16	3	1	24.0

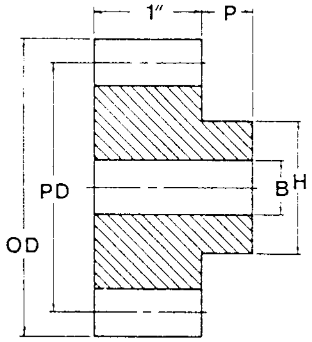
*Recommended Maximum Bore With Keyway and Set Screw
• = Will be discontinued as a stock size when current inventory is depleted. Check Steel.

14½° P.A. Gears Will Not Operate With 20° P.A.

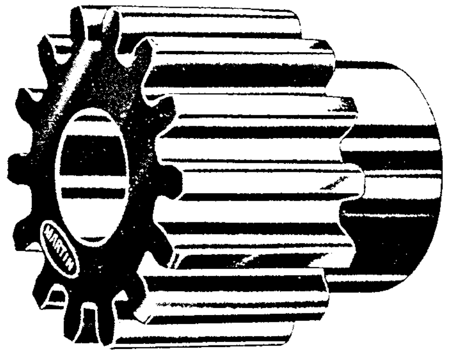
10 DP 1" Face Steel Stock Spur Gears

14½° Pressure Angle

Martin



TYPE B



TYPE B
PLAIN WITH HUB

Steel

No. Teeth	Catalog Number	Diameter		Type	Bore (Inches)		Hub (Inches)		Weight Lbs. (App.)
		Pitch	Outside		Stock	Max.*	Dia.	Proj.	
11	S1011 14½	1.200†	1.400	B	5/8	**	15/16	5/8	.3
12	S1012 14½	1.200	1.400	B	5/8	**	15/16	5/8	.3
13	S1013 14½	1.300	1.500	B	5/8	**	1	5/8	.3
14	S1014 14½	1.400	1.600	B	5/8	5/8	1 1/8	5/8	.4
15	S1015 14½	1.500	1.700	B	3/4	3/4	1 7/32	5/8	.5
16	S1016 14½	1.600	1.800	B	3/4	3/4	1 5/16	5/8	.6
17	S1017 14½	1.700	1.900	B	3/4	13/16	1 3/8	5/8	.6
18	S1018 14½	1.800	2.000	B	3/4	7/8	1 17/32	5/8	.8
19	S1019 14½	1.900	2.100	B	3/4	7/8	1 9/16	5/8	.9
20	S1020 14½	2.000	2.200	B	3/4	1	1 23/32	5/8	1.0
21	S1021 14½	2.100	2.300	B	3/4	1	1 3/4	5/8	1.2
22	S1022 14½	2.200	2.400	B	3/4	1 1/8	1 7/8	5/8	1.3
24	S1024 14½	2.400	2.600	B	3/4	1 1/4	2 1/8	5/8	1.6
25	S1025 14½	2.500	2.700	B	3/4	1 1/2	2 7/32	5/8	1.8
26	S1026 14½	2.600	2.800	B	3/4	1 1/4	2 1/8	5/8	1.9
28	S1028 14½	2.800	3.000	B	3/4	1 1/4	2 1/8	7/8	2.3
30	S1030 14½	3.000	3.200	B	3/4	1 1/4	2 1/8	7/8	2.6
32	S1032 14½	3.200	3.400	B	3/4	1 1/4	2 1/8	7/8	2.9
35	S1035 14½	3.500	3.700	B	3/4	1 5/16	2 1/4	7/8	3.4
36	S1036 14½	3.600	3.800	B	3/4	1 5/16	2 1/4	7/8	3.5
38	S1038 14½	3.800	4.000	B	3/4	1 5/16	2 1/4	7/8	3.8
40	S1040 14½	4.000	4.200	B	7/8	1 5/16	2 1/4	7/8	4.1
42	S1042 14½	4.200	4.400	B	7/8	1 5/16	2 1/4	7/8	4.5
45	S1045 14½	4.500	4.700	B	7/8	1 1/2	2 1/2	7/8	5.3
48	S1048 14½	4.800	5.000	B	7/8	1 1/2	2 1/2	7/8	5.9
50	S1050 14½	5.000	5.200	B	7/8	1 1/2	2 1/2	7/8	6.4
54	S1054 14½	5.400	5.600	B	7/8	1 1/2	2 1/2	7/8	7.8
55	S1055 14½	5.500	5.700	B	7/8	1 1/2	2 1/2	7/8	7.9
60	S1060 14½	6.000	6.200	B	7/8	1 1/2	2 1/2	7/8	8.7

*Recommended Maximum Bore With Keyway and Set Screw.
**Check Application With Factory
†Enlarged pitch diameter with special tooth form.

14½° P.A. Gears Will Not Operate With 20° P.A.

December 27, 1994

Uncle Sam
c/o Bill Clinton
President of the United States
The White House
600 Pennsylvania Avenue
Washington, D.C.

Dear Sir:

We are fully prepared to deliver to the U.S. Government for military base transportation use, one Pneumatic Passenger Automobile to meet specifications comparing to the electric vehicles they are spending millions of dollars on.

The Pneumatic vehicle has certain specifications not possible with other vehicles, gasoline, diesel, natural gas, propane or electric. We can deliver such a vehicle within six months of a purchase order from the U.S. Government. Our price is the same the U.S. Government is paying for the Chrysler electric mini vans. We can handle production costs ourselves, contrary to other electric vehicles.

Give us a contract Uncle Sam. We will do the rest. Just like the Wright brothers who got a contract for the first military airplane...we deserve a contract for the first Pneumatic Commuter Automobile for military on base use. All day and all night.

Pneumacom Corporation
511 Main Street
Joplin, Missouri 64801
United States of America

Toby Butterfield

Art Gideon

Terry Miller

ONE NATURAL GAS BURN IN A V-8 STATION ENGINE COMPRESSES AIR INTO CLEAN KINETIC ENERGY POWERING A FLEET OF CARS

Joplin International Autopneumatics Institute

Late Evening Conference
Phone 1-417-623-5261
10:00 p.m. till 1:00 a.m.

Air Station Location
National Muffler
920 E. 7th • Joplin, MO
1-417-781-6535

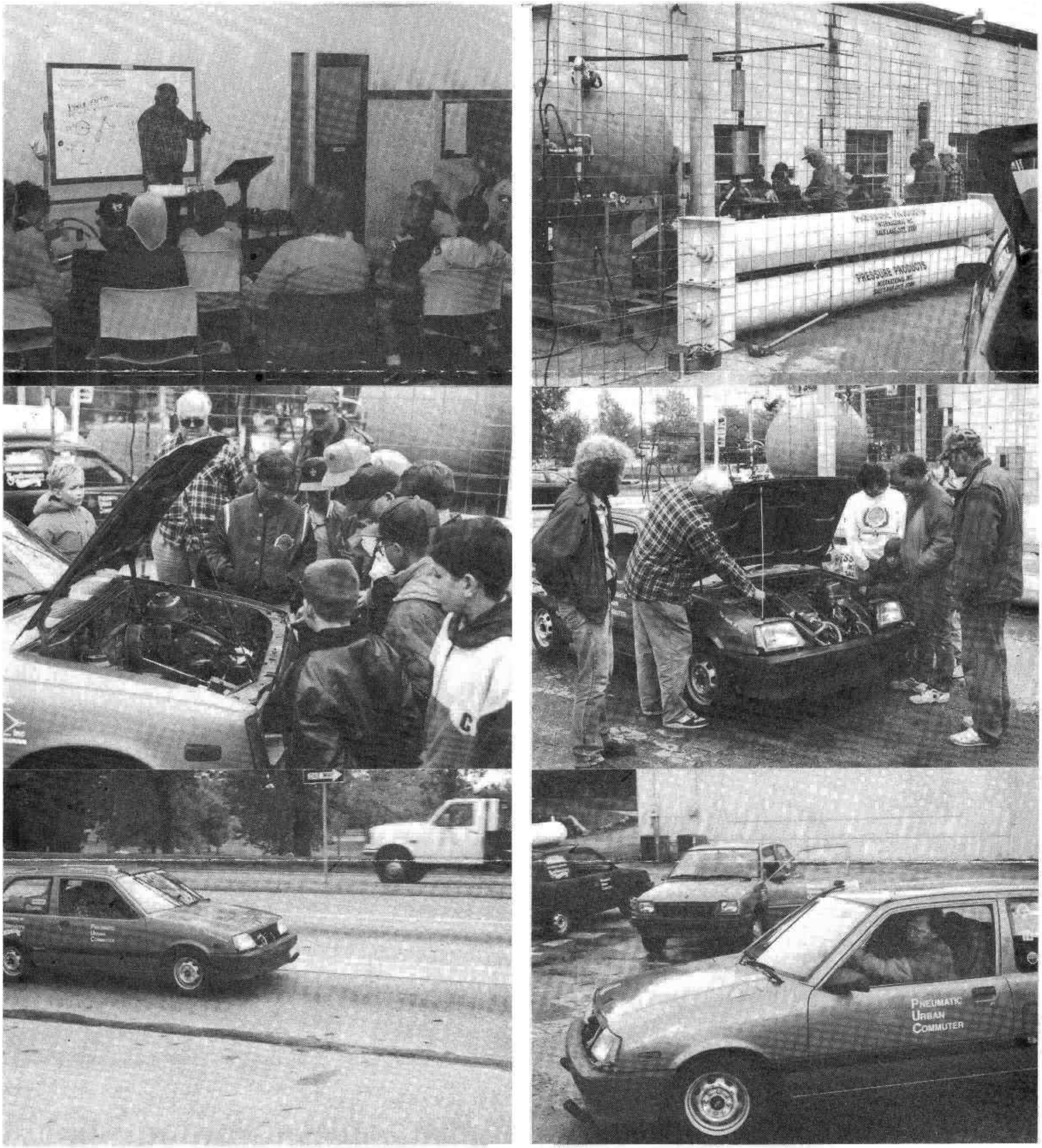
Joplin International
Autopneumatics
Institute

International Pneumatic
Urban Commuter
Club Joplin Chapter

Pneumacom Corporation

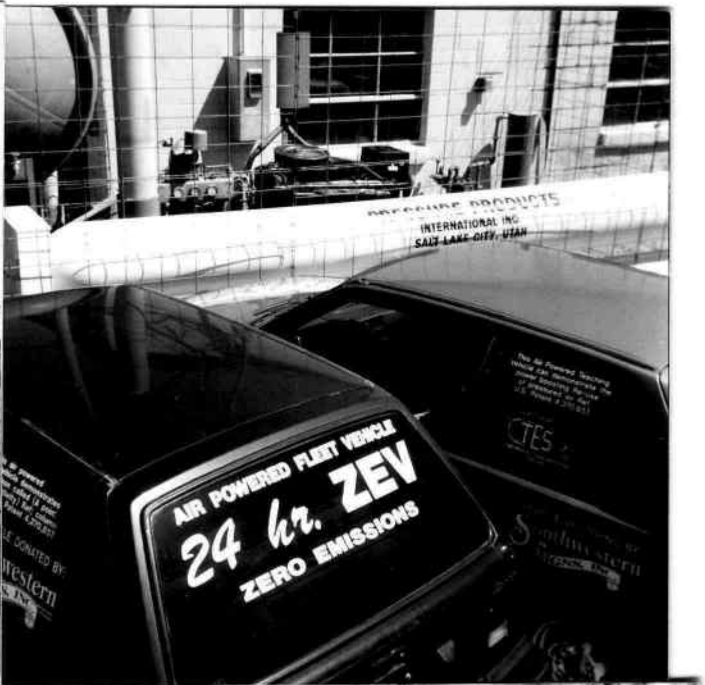
Offices: 511 Main • Joplin, MO 64801
Our Quick-dress is: Toby • 511 Main • Joplin, MO 64801

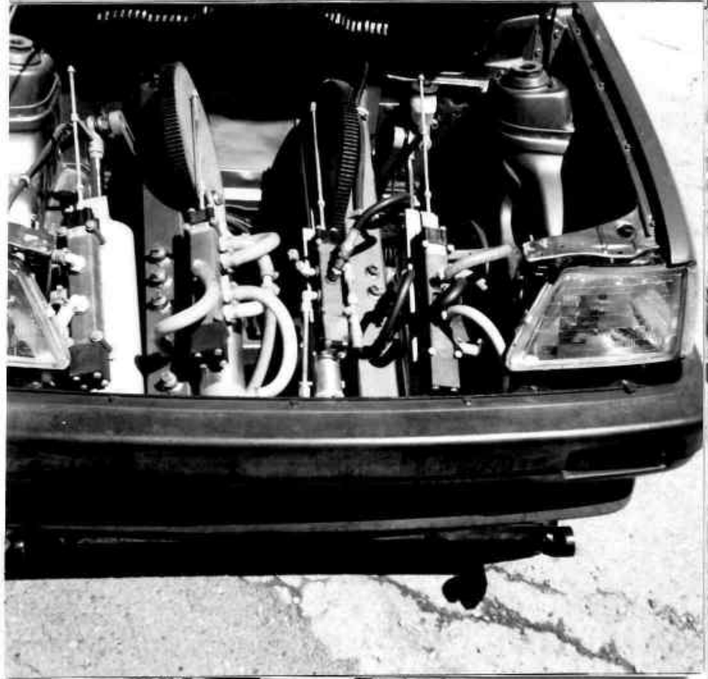
Public
Autopneumatics
Classes are
ongoing
Call for dates
1-417-624-5585

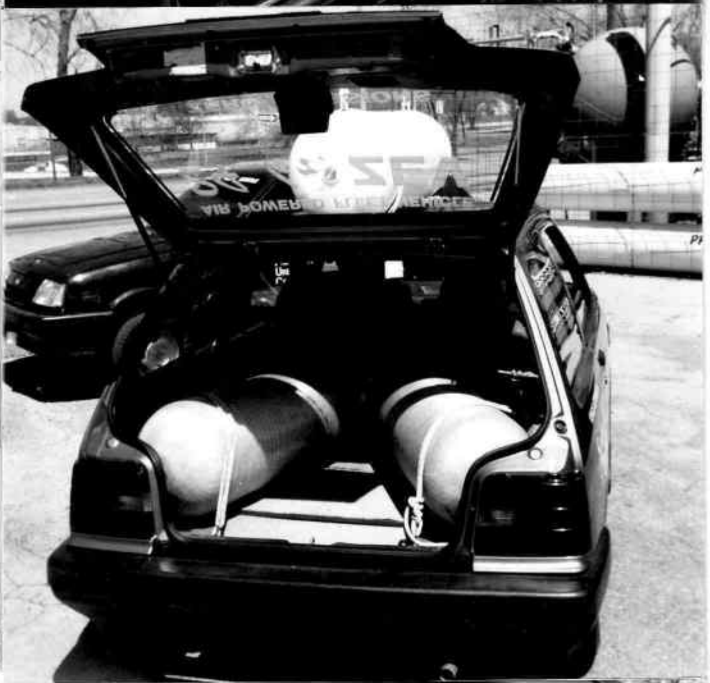


Joplin International Autopneumatics Institute theory and practical classes in Auto Pneumatics taught by the father of Air Car reality Terry Miller.

PUC
FILL & STATION


PRESSURE PRODUCTS
INTERNATIONAL INC
SALT LAKE CITY, UTAH
AIR POWERED FLEET VEHICLE
24 hr. ZEV
ZERO EMISSIONS

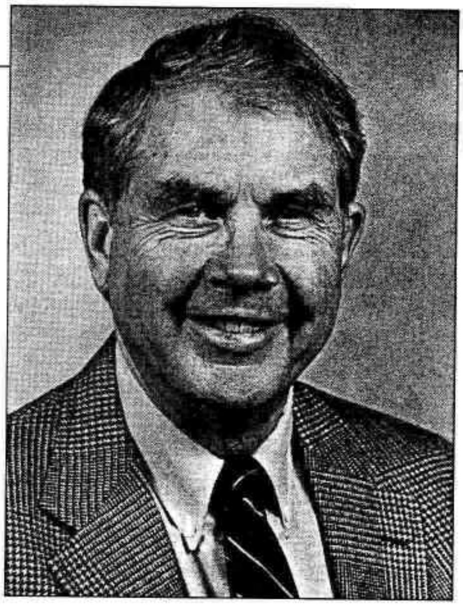




This air powered teaching vehicle demonstrates a phenomenon called (A point of non-productivity) Ref; column 10 line 55 U.S. Patent 4,370,857
THIS VEHICLE DONATED BY:
Southwestern
SIGNS, INC.
EST. 1986
AIR ONLY

This Air Powered Teaching Vehicle can demonstrate the power boosting Re-use of pressured air Ref; U.S. Patent 4,370,857
OUR THANKS TO:
TES Inc
TECHNICAL ENGINEERING SALES
AIR ONLY
VEHICLE LETTERING
Southweste
SIGNS, INC.
EST. 1986

EDITOR'S PAGE



With more than a little enthusiasm

This magazine traditionally focuses on mobile equipment in the same issue that previews the annual SAE International Off-Highway and Powerplant Congress & Exposition in Milwaukee, the largest industrial show that spotlights components for such equipment. Because mobile equipment is literally married to hydraulics, we seldom can find a pneumatic application to tie into that umbrella topic.

That situation seemed to be changing last year when we received a clipping from a Missouri newspaper about an air-powered car. The article was very light on technical details (I drew a mental picture of an on-board engine-driven compressor supplying air motors at the car wheels), so we wrote back to ask for more design information. This request resulted in a phone call from Toby Butterfield, who quickly explained how far off the mark my guess had been.

Toby is vice president of the International Pneumatic Urban Commuter Club in Joplin, Mo. He explained that the club's roots go back to 1983, when Terry Miller patented an engine powered by multiple pneumatic cylinders and valves, and using sequential expansion of compressed air. The club was formed to support and promote this new concept for transportationin vehicles similar to conventional motor cars. Members wanted to make Joplin the first center for teaching about and demonstrating the practicality of a new method of commuting. They liked the term *environmentally gentle*, and augmented it with *low cost* and *zero emission*.

Their mission expanded into its hardware phase by selling stock in Pneumacom, Inc., a more-formal corporate entity. Proceeds from the sale were combined with donations from club members, merchants, boosters, and just plain interested individuals to fund a drivable demonstration model. Components donated by supportive industries helped to make this project a reality. The resultant vehicle is described in our *Ideas & Applications* department, which follows on page 6. The Club believes that they are unique as air-car developers.

Next came construction of a pneumatic fast-refill station for the car, using an air compressor modified to be environmentally gentle, followed by retrofitting two more vehicles to create the present demonstration fleet.

Mr. Butterfield points out that for well over one hundred years researchers have tried to produce a battery to power electric motor cars. Even with Detroit's Big Three finally giving more than lip service to the quest today, a practical battery continues to elude them. The high-pressure pneumatic battery pack in the air-powered car may be the breakthrough that has escaped them so far.

It certainly appears that sometime in the future the American public will be forced to make a change in its driving habits and its attitude toward automobiles — probably making the car less of a cultural icon or personal statement than it is today. What form the car of the future will take is still unclear, but if enthusiasm in 1994 is a factor, the air-powered car will be a contender.

Dick Schneider

Dick Schneider
Editor

IDEAS & APPLICATIONS

By RICHARD T. SCHNEIDER

Air-powered car rolls through Joplin, Missouri

From a distance, *The Spirit of Joplin* looks like any other 1988 front-wheel-drive Chevrolet Sprint, but under the hood there's a major difference. This demonstration car is powered by compressed air — which, of course, produces no undesirable emissions.

The Spirit of Joplin is the most visible aspect of an ongoing teaching and demonstration project led by Pneumacom, Inc., with the goal of proving the practicality of air power for urban transportation. Its logical basic concept: if you remove the heaviest part of a traditional, gasoline-powered automobile — the engine — what's left will require less power to move.

The Sprint's internal combustion engine has been replaced by a patented arrangement of four 10-in.-stroke, double-acting pneumatic cylinders (two for each front wheel) that power the car in a mode similar to a fixed 7:1 gear ratio transmission. This type of acceleration and a top speed of 35 mph are fine for commuting in Joplin traffic. A manifolded 3-pack of cylindrical receivers, reinforced with carbon-fiber wrapping, in the rear of the car holds enough 3000-psi air to provide the 1500-lb *Spirit* with a 50-mile cruising range.

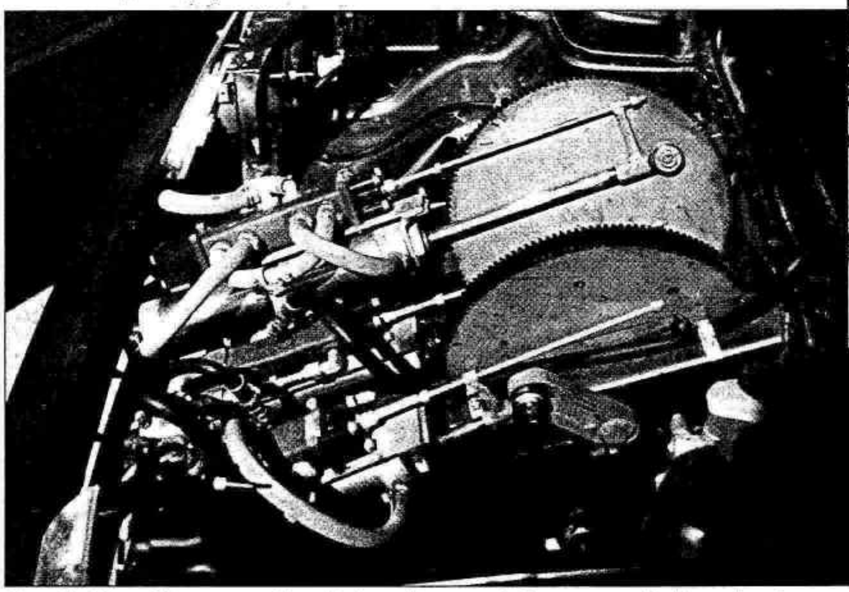
The cylinder bore diameters are progressively larger — 2, 2½, 3, and 4 in. — and they are piped in series from small cylinder exhaust port to next-larger cylinder inlet port. The result: each cylinder delivers about the same force to its crank to drive the *Spirit's* wheels. To relieve the backpressure that would impede their pistons, the cylinder's piped exhausts vent automatically at mid-stroke. Venting is timed to coincide with each crank's maximum torque position. The cool-running engine (typical maximum speed: 40 rpm) produces little vibration and no heat. It requires no case oil and filter, ignition and carburation systems, or radiator and antifreeze.

Steering has not been changed, and conventional hydraulic brakes stop the car with the original brake pedal. Reversing the cylinder power strokes reverses travel direction. Other driver controls are on/off valves for each receiver, an adjustable pressure regulator (mounted between the two front seats) that limits inlet pressure to 500 psi and also serves as a manual throttle, and a conventional parking brake.

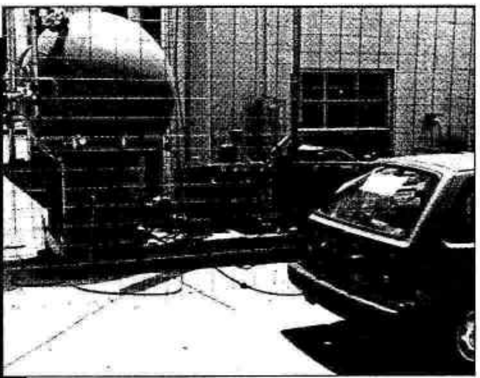
The first of nine planned compressed-air refill stations to be located in Joplin uses an engine-driven compressor. The V-8 engine is carburated to burn natural gas directly from a commercial service meter. Stationary exhaust scrubbers hold engine emissions to a minimum. When the demonstration car pulls in for a refill, a simple pneumatic quick-acting coupling makes the compressor-to-receiver-pack connection.

Earlier this year, *The Spirit of Joplin* successfully completed a 12-hour endurance test, with time out for refilling and short breaks, at speeds of 30 to 35 mph to add more credence to its practicality. Future plans call for substituting lightweight composite cylinders, adding more receiver volume to increase range, and installing 3- or 4-speed transmissions to improve acceleration and top speed, making driving even more like conventional automobiles. Roof-mounted solar panels could power a radio and other electrical accessories.

Air hoses showing in grill area are first external hint that Spirit of Joplin is not a conventional, gasoline engine automobile.



Four double-acting pneumatic cylinders drive cranks to power each drive wheel.



Demonstration car recharges its receiver pack at fill station in about four minutes.

Among corporate donor/sponsors who contributed to the air car are: Bimba Mfg. Co., Comdyne 1, Inc., Ingersoll-Rand, Linn Gear Co., Luxfer USA Ltd., Rexroth Worldwide Pneumatics, and Sherwood Div. of Harsco Corp.

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Spirit of Joplin blows into town

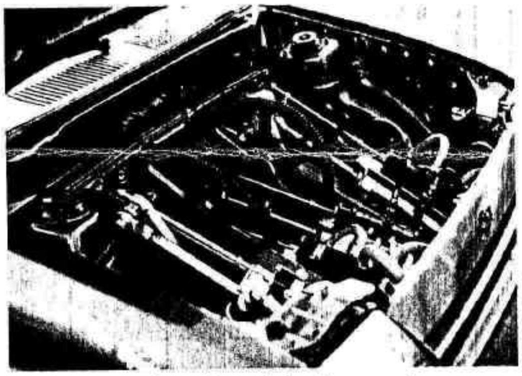
Jonathan Beard, New York

WHILE car makers around the world are struggling to develop exotic batteries and ultra-high-speed flywheels to power the nonpolluting car of the future, a team of researchers in Joplin, Missouri, has been road testing a zero-emission car that runs on compressed air.

"Most of the car is not custom-built, and we had no government funding", says Toby Butterfield, vice-president of Pneumacom, the company that built the car. "We began with a 1988 Chevrolet Sprint, and removed the gas tank, engine and transmission. We replaced the tank with three air cylinders." These are wrapped in fibreglass and carbon-fibre and contain air compressed to 20 megapascals, about 200 times atmospheric pressure.

The compressed air is fed by a hose to two engines, each driving one of the front wheels of the car. The left engine has two double-acting cylinders, one 50 millimetres in diameter with a 254-millimetre stroke, and the other with a 63-millimetre bore. The air enters the first cylinder at 3·5 megapascals, expands to drive the piston, and is then exhausted into a holding chamber, to be fed into the second, larger cylinder.

A second hose takes the exhaust from the left engine to the first cylinder of the right engine, which has a 76-millimetre bore. The exhaust from this cylinder drives the fourth cylinder, which has a bore of 105 millimetres. Air leaves this cylinder at only 25 per cent above atmospheric pressure, and is vented.



Pneumacom

Green power: the only emission is more air

The piston rods on each engine turn a 140-tooth gear wheel, which in turn drives a 20-tooth gear on each front wheel. "In this prototype, the fixed 7:1 ratio allows the engine to drive the car at a top speed of about 60 kilometres per hour," Butterfield says.

In March the team tested the car, named Spirit of Joplin, by driving it for 12 hours through the traffic of its home town, stopping only to change drivers and refill the air tanks. A charge lasts two and a half hours, and refilling takes about four minutes.

The compressed air comes from Pneumacom's own "filling station", a compressor powered by a standard V8 engine, modified to run on natural gas to reduce emissions. "But compressed air at this pressure is not hard to find," Butterfield points out. "We could stop at any fire station or scuba shop, and use the air they fill breathing tanks with."

The Pneumacom system was designed by the company's president, Terry Miller, an engineer in Joplin. "Most components were donated, and the labour was volunteered. I estimate that a production vehicle would cost about $10 000," he says. With funding from government, or the compressed-air or hydraulics industries, he believes that the firm could produce a car with greater range, a more efficient engine and a multispeed transmission, giving it the handling of a petrol-powered car and a top speed of 90 kilometres per hour. □

East Enders sue for two years without EastEnders

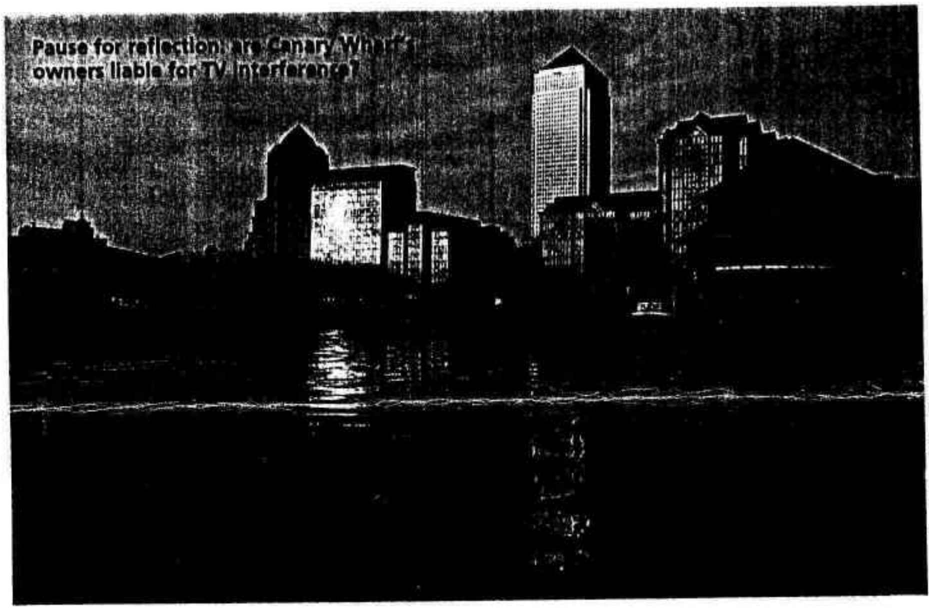
AN ENGLISH judge is seeking to answer a tricky question of modern life: do people have a right to TV reception?

Seven hundred people in east London are claiming damages from the owners of the Canary Wharf tower in Docklands, which has blocked TV signals reaching them from London's main transmitter at Crystal Palace. Many more people whose TV reception has been spoilt by the construction of tall buildings are awaiting the result of the High Court action with interest, as they might sue too.

Though the London viewers now have their pictures back, thanks to a secondary transmitter built by the BBC, they are suing for at least two years' "lost" reception. In 1989, as the Canary Wharf tower grew taller, at least 10 000 people in Poplar and Bow lost reception of all four terrestrial TV channels. In many cases screens went completely blank. About 100 000 viewers in the Lea Valley area to the north still suffer interference that cannot be rectified.

Viewers in the Lea Valley see ghost images on their screens caused by reflections of the signal from the tower's flat metallic surfaces. The affected area is wedge-shaped, only a few kilometres wide but many kilometres long. The BBC says that nothing can be done to help these viewers. Any secondary transmitter would have to transmit at high power, causing interference as far north as Manchester.

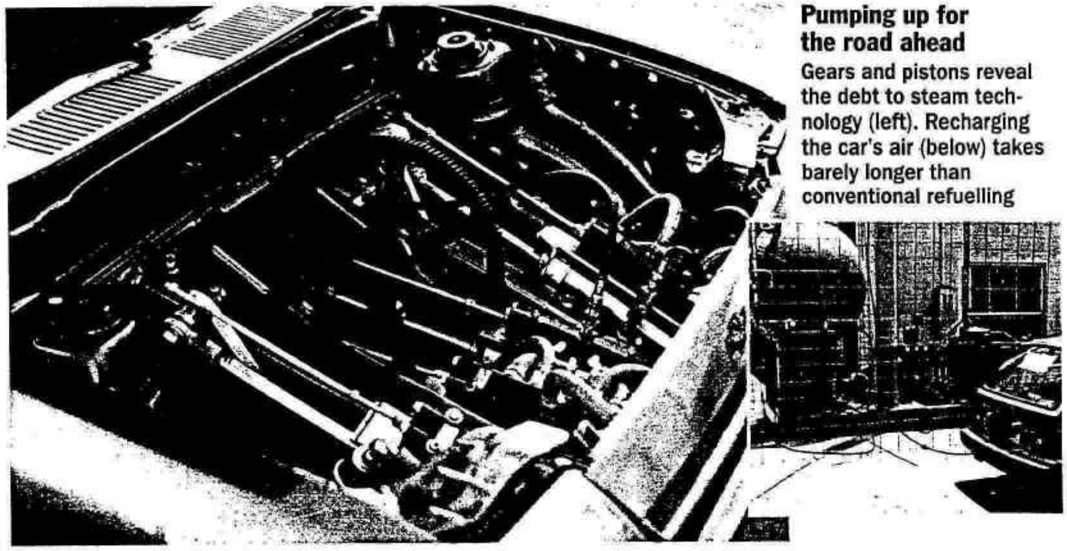
"The Canary Wharf case will create a very important precedent," says Anne Braley, acting for the plaintiffs. She is awaiting the ruling of the judge, Richard Havery, on whether householders have a legal right to receive TV pictures, and whether the owners of Canary Wharf have a case to answer. In England, all past attempts at suing over lost reception have failed, but the Poplar residents are encouraged by a case in Canada in 1984, when a cable TV company won damages from Ontario Hydro, which put up a building that blocked a wireless feed to subscribers **Barry Fox**



Pause for reflection: are Canary Wharf's owners liable for TV interference?

A. Woolfitt/Robert Harding

Focus - November 1994



Pumping up for the road ahead
Gears and pistons reveal the debt to steam technology (left). Recharging the car's air (below) takes barely longer than conventional refuelling

THE CAR THAT RUNS ON FRESH AIR

A car so environmentally friendly it could be described as a breath of fresh air has been developed by a small American company. Developers at Pneumacom are betting that the clean fuel of the future will not be hydrogen or natural gas (let alone petrol, diesel or electricity) – but air.

In an early prototype, compressed air is stored in pressurised cylinders that take the place of a conventional fuel tank. The result is a car that emits no exhaust pollution and is virtually silent.

In advanced steam-age mechanics, something called a compound steam engine was used to wring the last joule of energy from pressurised steam. Pneumacom uses a modern incarnation of the compound principle to do the same with compressed air – two compound motors are used to drive one front wheel each.

These two motors each comprise two double-acting cylinders of different diameters, which are connected one after another; the second cylinder is driven by the spent air from the first.

The left motor runs directly off the air cylinders, in which the air is compressed to about 200 times atmospheric pressure, or 200 bars. Air is bled off at just 3.5 bars to drive the first (smallest) cylinder, which has a bore of 50 mm. Its exhaust drives the second cylinder, whose 63 mm bore is calculated to extract the same energy from the now lower-pressure air.

A hose then carries the second cylinder's exhaust across from the second cylinder of the left motor to the first cylinder of the right motor. This cylinder has a larger bore (76 mm) to compensate for the further reduced air pressure.

Lastly the air passes to the right motor's second, 115 mm-bore cylinder. Air finally exhausts from this, at only 1.25 bars, most of its potential energy having been converted into work.

The prototype car, which was developed on a shoe-string, can run for two and a half hours in urban traffic. Recharging takes four minutes. A fully developed vehicle would be able to travel further, at up to 56 mph, and cost only about £6000.

Pneumacom compresses air using power generated by natural gas, but air could be generated by whatever power source – from nuclear to hydroelectric – is most efficiently available in the area.
Pneumacom: 010 1 417 624 5585

How Range Rover put body roll in the service of comfort

Since its introduction 24 years ago, the Range Rover has become the ultimate go-anywhere status symbol. With the latest model, launched this autumn, comes a still more ambitious design brief: to poach buyers from the likes of Mercedes, Jaguar and Lexus.

To stand any chance, the Land Rover design team had to provide its off-roader with on-road manners to match those of a luxury saloon. The suspension engineers' task was to achieve this without any sacrifice of the vehicle's legendary ability to plug the mud.

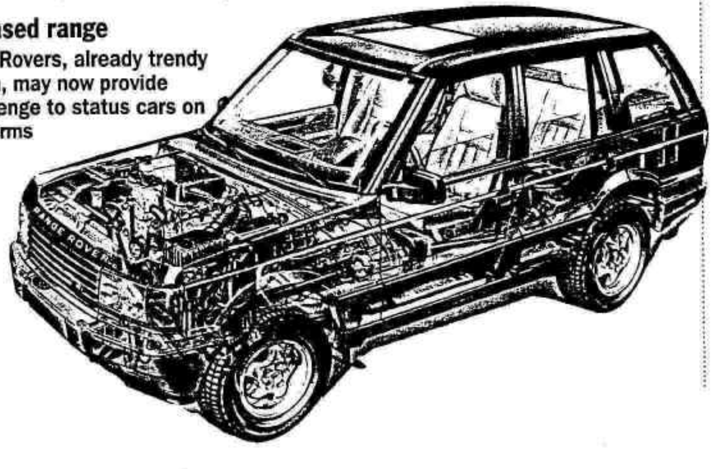
Providing the long wheel travel and gentle suspension necessary for a top-class ride was straightforward enough.

Reducing body roll round corners – a problem with any off-roader, caused by the high centre of gravity – was achieved by increasing the suspension's roll stiffness and stiffening the dampers.

But this still left the basic problem that characterises all large off-roaders – ponderous, truck-like steering response. To beat this problem, Land Rover's suspension engineers employed a feature increasingly used in the car industry: passive rear-wheel steering.

This is not the same as four-wheel steering, in which the rear wheels are actively turned. In passive rear steer the wheels turn as a result of the way the suspension is designed – in response to body roll. When the body of the car leans during cornering, the rear axle turns into the bend – not by very much, but by enough to produce a degree of cornering force from the rear tyres.

This "roll understeer" improves steering response, giving the driver the reassuring feeling of driving a vehicle that responds rapidly to steering commands.
Land Rover: 021 722 2424



Increased range
Range Rovers, already trendy in town, may now provide a challenge to status cars on their terms

In brief

■ That'll do nicely

High-tech companies seem to relish no challenge more than making motorists pay as they go. DeTe Mobil of Bonn has developed a particularly powerful method using the Global Positioning System. As the car passes through invisible toll regions its owner's smartcard is billed automatically by phone.
DeTe Mobil: 010 49 228 9360

■ Side-impact bars may be dangerous

Just when the industry's marketing men have persuaded us that side-impact bars are vital, crash experts are claiming the things can increase injuries. According to Professor Adrian Hobbs of the Transport Research Laboratory, in a full side-impact some door beams can concentrate the force on the occupant's chest. "What you want," he says, "is a strong support pillar but a soft door." This would spread the load over the pelvis and chest and push you away from the intrusion.
TRL: 0344 773131

Joplin International Autopneumatics Institute Pneumacom Corporation 511 Main • Joplin, MO 64801 (417)624-5585

A transcript of the presentation made to Mr. Ralph Fleming, representing the U.S. Department of Energy, on July 6, 1994 at the Joplin Public Library, Joplin, Missouri.

Terry Miller: "The purpose of this presentation is to allow Ralph Fleming , a past resident of this area and a gentleman who does contract work for the U.S. Energy Department who is with us here today to return with his evaluation of our project and I understand he has been commissioned by the Energy Department to do this, to evaluate our air-powered car project.

...uh, those in attendance is, my name's Terry Miller,President of the club, and the school and ...and uh ... let's turn the tape recorders off for just a minute."

Ralph Fleming: "Is this club, this something you organized?"

Terry Miller: " Yeah, I put it together. I put yeah... uh... When I get to the club, I'll explain it."

Ralph Fleming: "Fine, just go ahead."

Terry Miller: "The purpose of this presentation is to review the technical aspects of our air-powered car project operating under Patent # 4370857. Mr. Ralph Fleming, uh, he has been commissioned by the Energy Department specifically by Mr. John J. Brogan to provide the energy department with a technical evaluation from an engineering standpoint of our project. He is in attendance, this is July 6, 1994, it's about eleven- fifteen in the morning, and we're at the Joplin Library. Those in attendance besides myself, Terry Miller, is Toby Butterfield, our Vice-President, Terri Robbins, our Executive Secretary, and John Robbins, our Treasurer. Now, we have three entities, the one that started first was the International Pneumatic Urban Commuter Club here in Joplin, Mo., we call it IPUC for short. IPUCC. Now the outgrowth of that because we wanted to have something for commercial applications was Pneumacom Corporation the logo up here on the bulletin board , there's an archaic symbol for air which we use as our logo. and, uh, we use pneuma for air and com which stands for commuter, urban commuter. An outgrowth of this, then, in order to teach the technology and teach what we are doing,uh, because it's our obligation to teach others how this works was a school that we started and in researching all of the possible names that we could, we couldn't find anybody who was using the word autopneumatics ,uh, so we glommed onto autopneumatics and unless somebody says we can't use it, we're very happy with it. So our school in our school we start with basic pneumatics for people who are totally unfamiliar with pneumatics and we go right on through how the car works and practically enough information to build your own. So we have the three, three things now we have the non-profit club which is the International Pneumatic Urban

Commuter Club, we have the Joplin International Auto-Pneumatics Institute which we hope to be able to teach this technology worldwide and then we have our corporation, the commercial aspect, Pneumacom corporation. Uh, I'm going to go through this presentation rather quickly if I can and I'm going to go through bearing in mind that Mr. Ralph Fleming is an engineer and this is just like Kindergarten a lot of this stuff. We'll go through it as quick as we can ,uh, I won't ask Mr. Fleming any questions, but I want him to feel free to stop me at any time and ask any question that he wants and we'll go ahead and do our best to answer it.

So the club has been in existence as the Joplin air-car club and we had teenagers building air-powered cars and when they got the car built, they would get a $400.00 prize after they demonstrated that the car would drive for six(6) miles on one tank of air and that it had passenger carrying capability and we had local merchants signed up at $10.00 a crack to do this.

But even at this time we had no ,uh, air station, we had to buy our bottled air. O.K. now the names we come up with for pneumatics is uh, explained pretty simply we can't see air, you can see the leaves blowing in the trees and people thought that the spirit was blowing the leaves so we come up with the name pneuma,uh, which is the name for spirit.

Now the Kinetic energy of conpressed gases has been known ,uh, we found an article in ***Popular Science*** magazine about the Kinetic Theory of gases and what we use is the kinetic energy in the expanding gases trying to get back to the atmosphere to power the car. So we ,uh, call our cars pneumatic urban commuters.

Now,uh, when anybody thinks about air-powered cars and especially the Energy Department's view of air-powered cars today has been that anybody that tries to work on an air-powered car or come up with an air-powered car doesn't have all of his oars in the water and I agree whole-heartedly, cause our patent attorney way back in '79 and '80 sent us patents by other people,uh, Raspotnik, Robinson, Minkus,Brown and Manor and all of these air-powered vehicles were designed to, in some way, act on a perpetual motion basis so, in other words, to make their own air as they went down the road.—

Now, due to the practice of the compressed gas industry and due to the fact that you can't buy air cheaply, anywhere in the world, uh, it would lead anybody that was wanting to experiment and dream about running a car on pneumatics to want to figure our a way to do it on a self-sustaining basis and we don't do this we are straight-forward enough to not be a dreamer that we can get something for nothing even though it has been quoted by the Energy Department that anybody who wants to run a car on air is trying to get something for nothing and we're not.

What we're trying to do, and we have succeeded in doing, is to get as far down the road as we can on a certain amount of air.

Now a basic overview of the compressed gas industry is important,uh , what is air? Air is about 80% oxygen, I mean 80% nitrogen and about 20% oxygen or O_2 and most people say oh I'm breathing oxygen well that's not true,uh, there is only one way the industry now is coming up with oxygen which there's many a patient in hoslpitals there's welding and cutting systems going on and while nitrogen, they're finding more uses for nitrogen. Just the other day there was somebody talking about fracking, the breaking up of rocks by pumping cold nitrogen down into a well and doing something with it. They are trying to sell nitrogen all the time. Alright, the way they come up with the oxygen that is used in the hospitals is by refrigeration. Let's imagine if we will, nine or eight or seven refrigeration units in a row and we bring air into the first refrigeration unit and chill the air down to about 30° and then down to 20° below and then down to -280° below on down until we reach the point of -280° at which the air is turned into a liquid.

This is being done in industrial gas installations all over the world and it costs money because there is electricity used to power all of the refrigeration units and the liquid floats in a column and oxygen being slightly heavier they can draw out the liquid oxygen out of one column and draw out the nitrogen out of another column.

So for every roughly one gallon of O2 that they make liquid oxygen that they separate out what would now be liquid air they've got five(5) gallons, I'm sorry, four(4) gallons of nitrogen 20% X 5 we've got four(4) gallons of nitrogen. O.K.

Uh, they've got a lot of nitrogen that they can't find any home for and if you'll check with any compressed gas plant in the United States, you'll find out that on a daily basis, as the nitrogen begins to warm up in the large tanks that they have it stored in or just simply because they have no place to put it, they vent it to the atmosphere.

So here is what happens to the price structure, anybody wanting to experiment with air the same as I did in '79, you go to the welding shop and you find out that they have air for sale right now today, well, I'm going to regress back to '79 because other things have happened since. If you went to a welding shop in '79, you would find compressed air for sale that they had compressed at possibly $9.00 per bottle and even though the welding outfit knew that I was experimenting with air-powered cars, they would still gives us a good price break on air, but if we wanted nitrogen, they would sell us nitrogen at $7.00 a bottle.

To this day, they do not want to sell compressed air, they'd rather sell you nitrogen and they would sell you nitrogen for a reason. Nitrogen is not an oxidizer so consequently your fittings and tools and appliances and whatever you are wanting to power with compressed air like the dentist in the dentist's office or just a tinkerer wanting to by a tank of air,uh, you might as well buy nitrogen cause it's cheaper and it's not an oxidizer.

Now since my early experiments even back not too many years ago,uh, there's been a time back seven or eight years ago, I'm not exactly sure when, that they got around to the point that all compressed air being sold had to be certified breathing air. Now! Certified breathing air means that they take all of the impurities, they take all of the oil that might be in it because if scuba tank divers went to the welding shop and bought a T-size cylinder of air to take to the creek with them or to the lake and they filled their scuba tanks with this compressed air that was available and it had a little oil in it, then they could end up getting pneumonia.

So automatically, we find that sometimes in some parts of the country, you can find a T-size cylinder of air with only 240 cubic feet of air in it costing as much as $38.00 a tank full. But if you want to buy nitrogen to run something with at that same welding shop, you might find nitrogen for $31.00 a tank. Ah, it's been this way and it's been this way forever.

So it only stands to reason why ,uh, four to six patents were granted about every year up till 1983 and these patents were granted like for air-powered vehicles and all these patents were granted to self-perpetuating type vehicles even though the patent office, if you have a perpetual motion machine and you send it in to have a patent on it in the patent office, the first thing that they will tell you is that we want to see your working model and they eliminate all of the perpetual motion machines things that way because ,uh, you can't violate the Second Law of Thermodynamics and you can't get something for nothing.

And this is right and this is also another reason why what we're doing when most any engineer,uh, with the Energy Department of the Patent Office hears about an air-powered car, they would write us off just as quickly as we would write off anybody who would come into us to talk about " well now all you need to do is to put a chain on the axle and let the chain turn the sprocket on the air compressor and make your own fuel as you go down the road" and then we head out the door cause it's a dreamer, you know, a perpetual motion type thing.

So what we have done is to come up the way to re-use the air and use it efficiently. and ,uh, the compressed gas industry, there is no reason why we should argue with their price structure, but we've ,uh, all the times we've demonstrated air-powered cars until the last year and one-half we had no airstation of our own, we'd still have to go buy air.

I think the last price I paid for air two and one-half years ago was $14.00 a T-size cylinder for air and I bought at approximately their cost because we were working on something good.

You can understand that $14.00 for a T-size cylinder of air that there is no economy in that whatsoever, but it has nothing to do with the cost of producing the air, none whatsoever.

So, the Department of Energy has a standard line for air-powered vehicles and we are in receipt of the basic standard line, and the basic standard line for air-powered vehicles is that they can't possibly go anywhere because they can't carry enough air on board, they are not energy efficient,uh, and they couldn't be commercially viable, but it stands to reason if you are trying to make your own air going down the road that any of these arguments that says that you can't haul 50 cans of beer along with you it would be the same thing. If it just won't work, it just won't work. But, our vehicles do.

What we want to do now,uh, we've talked about the price of air and, uh, the fact that it's not available to the public at a cheap price but we are just going to get back to basic pneumatics and right now we are going to say that we do have air at a cheap price and proceed on with a little bit about basic pneumatics.

This particular tank was used as a sort of a prototype, if you will, for the construction of the main motor frames of the engines which we build and it was used to weld and check out fittings and to find out ,uh, some welders think they can weld and when they weld around something, they'll overlap a cold weld and you'll end up with a leak ,uh, I imagine that in pipeline welding they have that same problem. This tank is 1/8 inch in thickness and it has been subjected to 1300 lbs of air pressure. I put it down in the steel frame of our air station about two and one-half years ago, cranked up the regulated pressure but I was nowhere near it and nothing else was near it it just to see how much pressure it would hold. And on the basis of this test, we've made our motor frames out of this type of material. This will show you what the Kinetic energy of compressed air will do.**(Note: Test tank mentioned is three inch square welded steel tubing seven inches long with 1/8 in thick steel plate ends. Kinetic energy rounded the tank like a football.)**

Yet, in spite of this right now, we read an article in the paper the other day in the ***Joplin Globe*** where the big three automakers in order to get more range out of their CNG vehicles are planning on building air tanks into the frames of the cars. Uh, I sure hope it works because if it works for them, it will work for us too to carry air in it."

Ralph Fleming: "You mean CNG tanks."

Terry Miller: "Yeah, the CNG people, Chrysler, Dodge and the big three were quoted as saying that they are exploring avenues to build air tanks into the frames. I would imagine from an engineering standpoint you might shake your head the same as somebody coming in and saying that I've got a perpetual motion machine cause this is a clear demonstration of what Kinetic energy will do to any tank that isn't round I mean it, we don't know what will happen but with the new carbon fiber it may turn out just right.

So we carry air in our cars in tanks, high pressured tanks and we can fill them up to 3000 lbs of pressure and the nice thing about air which I'd say at this time is that compared to CNG we could go up to 5000 lbs of pressure. Uh, it's even technically possible. I mean the air pressure that we are using right now is considered in the industry to be medium pressure. I perceive the day, well, right now they use 3600 for natural gas but I understand, I'm not, I don't want to be shot down on this but I have understood that if you compress natural gas much higher in pressure that it has the tendency to liquify. I don't know, that's an engineering problem but all I'm saying is we don't have that problem with air. When we have tanks that will hold 5000 lbs of pressure. Right now we have air in storage that we can(pause)we can store at 4400 lbs and that's even before we even hit the safety valve so we have the capacity to compress to high pressures. So we have the tanks in our car and we need to have some way to regulate the Kinetic energy in the air pressure down to a lower pressure to operate our engine and, the "Spirit of Joplin" car operates on a pressure of 10-12 lbs on up to 500 lbs of pressure and we have a stop on the regulator ,uh, I'll just hand this regulator to you. You can put it back here if you like.

When driving the car, you need to understand that the regulator is opposite in action from a faucet. Like you turn a faucet clockwise to turn it off, well if you turn a regulator clockwise you'll be turning the pressure up, and you back the regulator back counter-clockwise to slow the car down or to slow or to cut your pressure down. Standard the two are opposite. There's not too much of a problem there. Now your tanks have to have very heavy duty faucets there are different kinds. Sherwood happens to be one of our international sponsors and they will supply us with anything we need in the way of valves.

The valve bodies are heavier but that is just a plain old faucet except it has to have different types seals for different types of gases.

Then, of course, for kinetic energy you need to know how much pressure you have, how much pressure is in your tanks that are in your cars that hold the Kinetic energy and how much pressure you're putting to the engine.

There are basic aneroid types direct reading valve pressure gauges and in the industry all of the different types of tanks like argon, nitrogen and air and oxygen all have a different tank valve, so you don't get them mixed up. We sure wouldn't want anybody to throw an oxygen tank into our car and start driving with it because the amounts of oxygen wouldn't mix with the oil in the engine so we are very careful to see that they don't get mixed up.

Besides the valves the basic faucet valves on these tanks a lot of the valves have safety devices like this particular safety device is a cap on the end that will blow out above a certain pressure like if your car were in a building and the building burns down and the pressure in the tank gets so high before it ruptures the tank it will relieve your pressure. One nice thing about relieving air pressure is it's not nearly as explosive as the same problem with CNG.

Here's another cap, a relief. We have some tanks in the car and one particular on the car that has a thermal device too it will blow according to pressure and the thermal device is like a sprinkler in your industrial buildings so that when the temperature gets high, it will relieve the gas. Very good safety devices.

Now besides all of your safety devices that you need for air, you need plumbing to make it go where you want it to go in the engine to go from one cylinder to another and to transport the kinetic energy from one place to another. Once you get your pressure down to a regulated pressure then we have other devices.

Another one is your blow out caps for your tanks. We utilize different valves A ball valve is simply a lot like the ball valve that you use to turn your gas appliances off in your home only we use ball valves for turning the engine off, for bleeding off tank pressure and different things.

Then we have faucet type valves and some needle type valves that we have used. You have to have some way to get the Kinetic energy to go where you want it and to do what you want it to do.

And then once the pressure is regulated down to your pressure that you want to use in your engine, you need some devices to protect your engine. So we use other safety devices, a basic check valve is used in our systems,some of our re-use tanks have a safety valve on them so if the pressure gets up high it will release just like an air compressor tank. Check valves play a very important part in our project.

The fittings that we use on our vehicles a lot of them are dead ends and 90's they restrict air flow the expediency of the air flow somewhat. A very important valve that we use for fill on our cars is a Hanson valve it's high pressure. When it's disconnected, it also acts as a check valve and when you hook it up, it will allow the gas to flow and when you disconnect it and also you can't hook it up if you have too much pressure on it.

So valves and plumbing are very important in our pneumatic system. I'm sure it's old hat for somebody in the business. Another very important valve and this is probably the most popular valve that we could ever think of using, we haven't ever found found anything else we can use, is the old Webco Westinghouse air brake valve. It has a spool inside and I had the privilege of talking with the man who designed or invented the valve and I asked him if in his day he has ever found any other valve that all the cylinder, I mean all the ports, can be clocked. We put this in one installation in the engine on top of a cylinder to vent and port your air and all you have to do is to pull the rods on the side of each one of these segments will rotate and as your segments on the valves are held together we have the brass bushings the bronze bushings and the O-ring seals that keeps the air from going from one portion on the spool to another. So as the spool inside this valve moves back and forth it allows the air to go from one port to the other by just holding the valve in this position this center valve say is your pressure always your pressure so when then the spool in one direction and the indent in the spool slides over to where it connects this port and this port then it turns this port temporarily into a pressure port, and that allows the air to flow through connecting these two ports and pushing on either the push or the pull port of the cylinder making the cylinder work.

Now by the same token when the spool is moved in the opposite direction, these two ports that are connected together won't be connected together anymore but the port that used to be supplying pressure when the spool valve slides over, it will be connected to the port which would allow the air to escape and it turns it into an exhaust port and the the opposite port would be your pressure port and they are called, they are four-way valves with a tapped exhaust. By tapped exhaust means that all the exhaust ports are just simply plumbing tapered piped tapped so we can save and re-use the air.

Now these Westinghouse air brake valves are simple they are easy to overhaul however the first one, we've been at this since, I took a valve off the original patent vehicle that I purchased in 1979 and it was leaking between the sections and I took it apart, disassembled it out, slightly lubed the O-rings with a little silicon and put it back together and that means that valve was in existence from '79 to just about a year ago. They are pretty easy to overhaul. Another thing about these spool valves is that we've been in touch with Bimba Cylinder Mfg. Co. and its possible to take a spool valve and have the ports on the cylinders machined so it instead of having to plumb it you can actually set it on there and it will snap into place and the spool valve will become mounted pneumatically with the cylinder.

If our intentions turn out right, we will be able to supply you with a complete set of tapes plus a typewritten transcript..."

Ralph Fleming: "Do you have some operating vehicles somewhere?"

Terry Miller: "Three, we have a fleet of cars.

The way our valves are timed is that we have a rod tied to the end of the spool valve and at the end of each cylinder we have a rod end attached to the end of each rod and on this rod end I'll draw a quick picture here ,the cylinder rod is screwed onto there.

We have a striker with a nut welded on here with a hole in it and the rod is 1/4 in. steel rod and it is attached to the end of your spool valve for timing. Now as the cylinder goes to bottom dead center, or top dead center where you are not getting any torque but its time to reverse the air flow in the spool valve it takes 5/8 inch of travel on this spool valve right here in order to change the direction of the air flow

And as the spool valve slides back and forth there's a time in-between where there is no air flow at all and we have a reward out for anybody who can come up with a better, this is not bragging that we've got the best but we are seriously looking for someone who can come up with what we have is a set collar here and a set collar here and we are looking for someone who can come up with something that won't take about 16° of crank shaft rotation in order for the striker to hit this rod and as the crank goes around you've got the area here, so many degrees of rotation that it takes to move this spool valve from push to pull and then also there is a period in between where all of the air hoses are locked up but fortunately when all of your air hoses are locked up your piston is back here or up here either at the push part of the stroke or the pull part of the stroke and there is a little bit of drag here. Now if anybody could come up with a bolt-action type .22 ,uh, loading type trigger cocking mechanism where by you would get the top dead center or bottom dead center and when it hits here it would go ahead and click it over like that and then on the way back it would compress the spring so when you get to this end it would click it over.

So we're quite confident that anybody that can improve on this timing could obtain a patent cause I've tried to figure it out for about four years now, something better, we used to have a cam operated um spool valve and our vehicles for quite a while that we that we had had a cam and a return spring so all the cam would have to do would be to compress the spring and the cam rolled over the roller and compressed the spring and then your once the cam dropped off her you'd get a rather instantaneous change back, this was pretty fast timing but it required extra long hoses and sometimes the return spring and the cam follower wouldn't work right if it were a little bit dusty and the method we have now of the push rod timing is very reliable, uh, we got together with the Crowder crew ,uh wasn't it about two years ago in front of your establishment, Mr. Butterfield?"

Toby Butterfield: "Correct."

Terry Miller: "And the Crowder College crew,uh, the kids were getting the students were getting rather excited about the possibility of putting a solar panel on the roof. And then,uh, going ahead and having a solenoid to operate the spool valve now granted that would give you sharp pretty fast timing.

Uh, I'm a little leary of the gremlins that you can have in the timing because you don't want your cylinder to be saying I need to push when the car is saying, no you're not, we're going to make you pull. Uh, We've been very fortunate in that the push rod timing has proven very reliable and we have a detent kit on the Spirit of Joplin car and on ,uh, both our demonstration cars we've put a simulated drag on here, uh, which we have to adjust from time to time so when the, when the striker is sliding up and down the tube, it won't catch the rod,uh, I mean when the striker is sliding up and down the rod, it won't catch the rod and move the spool to the wrong position. But the other two cars that don't have the detent or that we use for instruction purposes it works all right we, we show how far they will without re-using the air then how far they'll go with.

And our teaching vehicles work out real good. Uh, so if anybody comes up with ,uh, with,uh, an improved timing of a mechanical nature, we have a thousand dollar reward and I'd almost be able to guarantee that they could get a patent on it because it's not obvious to somebody skilled in the art. Well the patent was granted in '83. We're not really. We don't need patent evaluation of what we have because we're in technology we've learned so much since '79 and that ,uh, what we're seeking is,uh, funding from the government for teaching purposes and for demonstration purposes and to build a production prototype.

Before we go on, I just want to name our international sponsors and what they have helped us come up with. Bimba provides us with the cylinders that we need for the car and any time we need another set we get in touch with them and they ship them to us and our corporation is on a first name basis with Chris Shockley, who is their chief engineer. We don't go through distributors or nothing we talk directly to him.

Then Ingersoll-Rand ,uh, has sponsored us to the point of providing us with an air compressor and a lot of technical information and the gentleman's name in South Carolina. Toby, what's his name?"

Toby Butterfield: "Jack Culp, Jack Culp with Ingersoll Rand. He's the International Product Manager for Small Compressor Division of Ingersoll Rand."

Terry Miller: "Right. Now Comdyne Inc. is another contact which Toby Butterfield has made and they have supplied us with aluminum tanks which are composite wrapped and they're getting into CNG tanks which they're supplying gonna supply for the Chrysler vans to run on CNG. That's Robert Beresford, yeah Robert Beresford and he's up somewhere by Three-Mile Island somewhere isn't he? He's CEO and he's in West Liberty, Ohio.

Then Pressure Products international has supplied us with tanks for our air station. he and his wife drove all the way from Salt Lake City and he asked the same question you did. "do you have some cars that are running?" and "Can I drive one?" and I said yes.

And he said, "what do you need?" "I said air tanks." He and his wife drove all the way from Salt Lake City. he owns the second biggest maker of ,uh, high pressure of ,uh, pressure,uh, receivers in the United States.

And then Luxfer, everybody knows who they are. They're scuba tank manufacturers, they supplied us with the gears, I mean the air tanks for our first car which were oversized scuba tanks.

And then Linn Gear, they're in Oregon, supplied us with the with the larger gears, they're not in this picture, they provided us with solid steel gears because we were stripping the gears out of the cranks so they supplied us with solid steel gears.

We have many inter, many uh, sponsors here locally that are helping us with what we're doing. So we're going to get off sponsors and go onto something else.

Uh, it has always been a matter of conjecture and ,uh, myth,I would call it a myth, that air is subject to Ohm's law. Uh, the farmer goes out to paint his combine out in the field and the combine is 300 foot from the barn so he's got three sections of air hose and he goes to his friend's and borrows a couple more and you know what's gonna happen, he goes out there and he starts to spray and he pulls the trigger on the gun and the gun goes "Sppppp" That's all there is to it and then it sits there and blows in his ear without hurting his ear, I mean he's not getting any air.

Alright, he can run his electric cord out and he can move his compressor out to where the air station is and he can plug in his electric cord and he'll find that his electric cord will heat up and the motor on the compressor will get hot and finally he'll say he'll have to pull the combine over closer to the barn or if he wanted to he could get another air tank and set it next to his combine and hook up a hose from the barn to the air tank and in time he can smoke a cigarette in time the tank will equalize by pressure equalization transfer from one tank to the other and he can start spraying.

When he gets down, when this tank gets down to the 40 lbs below the 40 lbs that he needs to spray paint with he can stop and the compressor cranking away will eventually fill the big tank and him with this 30 foot hose he'll be back in business.

We have read and researched in the library about different uses for air and they used to use air right under Joplin here to move ore cars with and in the old round tables in the maintenance yards in Pittsburg, Kansas to move the locomotives in and out of the in out of the maintenance shops they'd hook up the air hose to the steam engine so they could use that to move their cars with they wouldn't have to fire up a boiler but ,uh, air pressure is something that Westinghouse considered using way back when they first wanted to harness Niagara Falls.

They wanted to,uh, figure out some way that they could transfer some energy to Buffalo, N.Y. and the problem they were having with D.C. electricity is that by the time it got there, they'd lose a lot of their energy and at that time their voltage wouldn't be reliable, they'd have to, to ,uh, resistor it down, or whatever they did,uh, in order to, to use the D.C. and they seriously considered using compressed air because while it was something that might not be fast in transit, it would be one that they wouldn't lose any of the energy.

Once they had compressed the air,uh, unless they let it back to mother nature, the energy would still be there.

We have, we have proven and, and we'd be tickled to death, tickled to death to demonstrate this but you can take two T-size cylinders or take three, one full say at 2400 lbs of pressure, the other one full at 2400 lbs of pressure and the other one empty and hook up a 100 foot hose and bleed the pressure off of one T-size cylinder by pressure equalization into the other one so you're gonna end up with two cylinders at roughly 1100 or 1200 lbs of pressure and another one with a full, full tank.

Okay you can drive one of our vehicles on a tank that has, that is full and set that tank aside and put the other cylinder on and drive until you won't go anymore and put the other cylinder on and you won't go anymore.

You can prove that the running the air through the hose and equalizing it and bleeding it off into the tank you didn't lose any of your energy as long as that air has the pressure equally to run your car on the energy is still there once you've got it compressed.

Now we conferred with Ingersoll-Rand, haven't we, Toby on this? And your head man in charge of international sales, Jack Culp, uh, he dragged out his computers and we haven't done this in a long time and he said that will work. He says, uh, so we had been had the confirmation that it's possible to have five or six air tanks storage facilities for Kinetic energy in town substations, yeah, and have one central plant,uh on the gas lines, at Williams Pipe and,uh, be using natural gas to compress air and we can bring it in, into town without losing any of the energy."

Toby Butterfield: "Right."???

Terry Miller: " Now granted, if somebody goes to a tank to fill up, that tank drops down maybe from 4000 lbs of pressure to 4400 lbs of pressure, down a couple hundred lbs of pressure but in time due to pressure equalization transfer from the other tanks or the main station, it will go ahead and fill back up but you just don't lose any energy just because it takes time for the air to get through. Uh, and that one particular thing is the basis of why this invention works.

The most important factor, period, in making this invention work is time. TIME. Now the first and only invention of all the inventions that the patent attorney ever sent to me was a fellow by the name of Raspotnik and it's a 1921 invention and he had a simple pedal car with,uh,this one is pointing to you and this one is 90° out, and he had a little double acting cylinder tied each one , it was a toy, and then each one of these cylinders had a valve to operate it and then it would have air supply and both cylinders had full pressure and it was a toy that worked.

And of all the doggone inventions I have seen, it's the only one that doesn't rely on perpetual motion.

So it's no wonder,uh, that some people in the Energy Dept. think that,that air, anybody thinking about air is looking for a miracle.

Also, the concept that air is energy is not energy efficient is wrong. Help, please, how many different ways is air used in an automobile today?

Now we're gonna lump in gas shocks for instance because maybe they have nitrogen in them but they are still operating on, if you'll pardon the fact that pneuma is supposed to stand for air, it can also stand for spirit-like, so let's lump in all the different gas operations in the car, there's the spark advance for the distributor. There's radiator pressure once and your hot water gets hot and you build up pressure on your radiator cap, 14,16,18 lbs, there's your shock for your lift door in back so the valve that turns on your hot water heater in your car is often operated by a little pneumatic diaphragm that turns on the hot water for your heater core.

There's air in your tires, the super charger on your car, you know, a turbo 250 or something like that they compress the air before it gets to the engine and then the engine compresses the air too.

In one vehicle one time, I think we come up with 15 uses for pneumatics in that vehicle.

So, from an engineering standpoint, if you can use pneumatics for all of these things in a vehicle, then why not see if you can carry enough energy on board to power the car?

And that's what we're getting into right now. The ,uh, maximum push, pull speed of a cylinder is how fast this cylinder can go back and forth and there's three, three things in the invention that are important to recognize and if your hoses and your fittings and everything have drag which they won't rob your, they won't rob the air of any of its Kinetic energy if you give it the time to work. You've got to give it the time to work.

It won't rob it of the Kinetic energy . The only time you lose your Kinetic energy is when you got 18, 20, 30 lbs left in the last cylinder of four that is used in your car and you let that back to mother nature. Uh, we hope eventually to have air engine that the exhaust will be like "phew" That's all there is to it.

Okay, now a cylinder there's a limit of how fast a cylinder will operate. That's with no pressure on it and I'm really working.

Now when you put 200 lbs of air in this side of the cylinder and blow this back and at the same time you're letting the air of 200 lbs out through your spool valve, pressure in escape. When you put the 200 lbs of air into the cylinder, it went through a hose and in an inch of that that hose which if it were full of water might only hold, hold let's say 1/4 of a cubic inch of water.

Now just a little amount of water in that whole section of hose, but compressed to 250 lbs you can be passing on, let's go back to 200 lbs, you can be passing on 200 lbs of air pressure through this hose and instead of just having the equivalent of 1/4 cubic inch in an inch of hose, you can have 7 cubic inches in that one small one inch area and it will go through the hose.

Right, when you get into your cylinder and you change your spool valve for timing,uh, that's just for the sake of,uh, pretending, here let's pretend we're just simply driving the vehicle with just this one cylinder."

Ralph Fleming: "Alright."

Terry Miller: " When you vent your air that you've already used to push the cylinder one way and you start decreasing the pressure, it has to go out this port and through the spool valve and through your plumbing and out to the atmosphere.

The minute you start dropping the pressure in that cylinder, the air starts to grow in volume and as the last of the air leaving this port is down to 50 lbs and it's grown in volume to four times the amount that it was in when it first entered the cylinder here so it was easier to put the air in the cylinder here as far as the force that it took because of drag and friction then it was to get it out at the end.

Which is another reason why if you're gonna get any energy out of the air, you have to allow the time for it to do it.

Okay, the maximum RPM that this engine will operate efficiently before it reaches the time when it becomes,uh, non-productive, from what we are trying to accomplish is 40 RPM's.

This is the only vehicle, sir, that you'll ever be able to drive that we know of where you can be clipping down the road at 25 MPH and you'll be able to count the RPM's in the engine because every time this car goes one time,every time this engine the crank every time the cylinder goes "pssss, pssss", you'll go 28 1/2 feet down the road.**(Note: Correction to 38 1/2 feet down the road)**

Now we had one test vehicle which, which we built to demonstrate what we call the point of non-productivity. Or, in other words, this engine is geared up one-to-one where every time the crankshaft goes around one time, one "psss,psss", the car goes only five feet four inches down the road. Now it stands to reason that in a very low speed you reach your point of non-productivity where this cylinder just won't go any faster.

It hasn't proven to be the best demonstration vehicle for the point of non-productivity, uh, the the the the car that we use to demonstrate the sequential re-use of air that I'll explain in a minute is really proven to be the best vehicle.

But this vehicle has also demonstrated the fact that if we can improve the timing through some mechanical means or go to electrical,uh, we will improve the speed of the vehicle because, uh, there's a certain amount of inches that this wheel rolls down the road when the spool valve has all of the air locked up and it can't go anywhere.

So the little red vehicle if you're patient with it as you observe what's going on it can teach the point of non-productivity and it can also teach the fact that the timing needs to be improved.

But we don't need an invention, we just need, need some engineering help on it, some of these rocket scientists from Cape Canaveral, that Clinton promised could help with this project.

Now, I want to get back to this point of non-productivity again which like I say, is one of the main, main things that I'm sure or I would hope that you have never had anybody talk about before Mr. Fleming. Uh, If let's say we had a thousand lbs of air pressure on this cylinder and this whole, this whole,uh, hose and cylinder had a thousand lbs of air pressure in it. I don't know but I'm gonna, what is it, theorize or speculate or something that if we didn't count the power factor which we'll get into in just a minute, but didn't count the power factor, the fact that this piston has a little less air in it, if the little rod here was say .010 of an inch in diameter and the power, the area on each side of the piston were the same, then I believe that if we had a thousand lbs of air pressure on this cylinder that I could go ahead and work this just as fast as if I had only two hundred lbs of air pressure on it.

Uh, that'd be something interesting to check out on a flow bench operation. One thing for sure, if it takes a certain amount of force to push the air from one side of the piston to the other and if you had one thousand lbs on it the minute you disconnect this hose and then try to do it again while this air is growing in,uh, your density of the air would become less I don't know if you would end up with a cylinder where your air would be expanding more and you'd have to push all that air out that force port and it would be changing from a thousand lbs of pressure and growing into maybe a hundred lbs of pressure and that would take a lot to get rid of which is the basis of the whole thing gets back to time. You've got to have the time to do this.

Alright, so we've got the time how are are we gonna use the time for our best benefit? Uh, any questions up to now?"

Ralph Fleming: "I don't have any about your discussion. I'll have some later on your experimental evidence."

Terry Miller: " Oh, right. We'd be tickled to death if you'll write down the things that you want to be shown and we'll tell you what we'd like to show you and, uh, I believe we'll get it done. Can you be patient with us?"

Ralph Fleming: "Yeah"

Terry Miller: "Okay, let's get into power factors of a cylinder if, if you've got cylinders that are progressively bigger in diameter, if we use if we could use the air more than one time and ,uh, which is what the invention does, or what our technology does.

If we use the air in this cylinder,uh, and the power factor allows us say, say we put in 500 lbs of pressure and we're able to get say 1800 lbs of force on our crank and our crank is five inches long, see then we can multiply our air pressure times the power factor to get the force and if we get the force in pounds pressure, then our crank will give us the torque we need. Or the torque will give us a torque. Once we take the air out of this cylinder through the spool valve and as I mentioned before, uh, the spool valve,uh, can be from what our engineers at Bimba tell us, can be mounted on top of the cylinders.

And they can be quick-changed with a couple snaps and lifted off and another one put on. So they're enthused about that.

Okay, If the pressure, if we use 500 in this cylinder and we have a tank that by some means we're able to take the exhaust air and save it, and the exhaust air comes in here at around 250 lbs or 245 lbs and in order to get the same pressure on the crank if we can save this exhaust air and plumb out of this tank into the spool valve and re-use the air, then if our power factor is larger enough like we're getting up to a power factor of 8,7, or 11 whatever it takes to times this times pressure to get the same force then we can before we let the air back to mother nature, we can re-use it again.

Then if we come up with a re-use tank here that's down to about 115 lbs of pressure and we put in a larger cylinder, we can get the same force again.

So what we have in our vehicle is,uh, four double acting cylinders and there to the best of our ability to attain dimensions, they're two, two and one-half, three and four, we'll give you all sorts of paper and information.

Uh, these cylinders are arranged, there's two drive the left wheel and they turn one crank. Two drive the right wheel and they turn the other crank so actually we have two engines but we have what has been termed and called and and the technology is sequential re-use of pressurized air, in other words we use the air ,uh, several times.

I believe that you can start out with a 5/8 inch bore cylinder at 1500 lbs pressure and graduate on up to a bore size of say six or seven inches, I believe you could use the air up to up to ten times. You know but when you got to the last big ole bore cylinder it wouldn't have much Kinetic energy left in it.

We also feel from our experiment and our design work that an urban commuter, to get around town cheaply, and do it on a 24 hour basis you're not talking about having to recharge for an hour or a 1/2 hour or something ,uh, we could be driving with a crank shaft with, uh, three cranks on it and three cylinders and then you'd have to go to a differential on your transmission so you could go around corners or driving in the car. But the way we are right now, we have one engine driving the left wheel and one engine driving the right wheel. So,uh, in the sequential re-use of the air is something that gives us more out of the air and ,uh, the fact that we go slow if, now the vehicle we have is ,uh, is geared to drive at 23 1/2 miles an hour at 40 RPM's."

Ralph Fleming: "Were split two and two."

Terry Miller: "Uh, huh."

Ralph Fleming: "... That's all one source of air, you're not, it's not a parallel thing?"

Terry Miller: " No"

Ralph Fleming: "You're going through?"

Terry Miller: "Right, ah, Mr. Fleming, it could be parallel, I have had it in a position before where I wanted to get the most of the air out at the end.

See,we usually stop driving at 500 lbs of pressure, because sometimes we want,uh, 500 lbs.

And I have plumbed the car before to put 500 lbs to the left engine and since the cylinder on the right engine the first three inch bore is rated at 250. I have put another regulator on there and by switching a couple valves and bleeding the air off the re-use tank, we're able to go ahead and drive that car till we're down to 50 lbs of pressure. And considering that we have three large tanks in the car, you're looking at another six or seven miles of range if you're willing to putt along in other words, it's emergency air if you need it. But since it really didn't do what we're wanting to do but we know we, we gained a lot of technology since '83, but yes the fact that we use the air over and over again and suck every last bit of Kinetic energy we can get out of it helps us to get there.

This would be a good time to review a letter that I wrote to,uh, Brian Tice and Shockley of Bimba and this is April of 1992, this is old, alright:

"Before production of engines for pneumatic commuters, a flow bench will have to be set up to establish the optimum cylinder bore and pressures for the most efficient re-use of air. Such a flow bench, test bench, if you will, with the ability to substitute sizes, stroke length, re-use tank sizes, hose diameter could quickly establish a set of guidelines for data that's reliable consistently.

Much the same way, the Wright Brothers established data for lift, airfoils and propeller pitch diameter and such.

Sequential re-use is proven, it's absolutely proven even with limited testing of various sizes of cylinders the object is to have all cylinders using design data at hand delivering the same force to the crank using exhaust air as the first cylinder did using the air the first time.

In a single crankshaft with three or four throws the stroke point to the cylinders could be adjusted to smooth out sequential air re-use from the cylinder to the tank to the cylinder and the receivers and on in the engine."

I'll give you a copy of that, I'll just lay it there.

Uh, yeah,uh, that's why there's probably oh counting all our students and all, there's probably fifty people in the world right now that have a pretty good understanding of how this works and, but let me go ahead and review the steps to discovery but let me first review the other cars we have in our fleet.

We explain that the red car due to the fact that it's a five to four ratio, we have another car which is a two to one, it goes about eleven feet down the road every time the cranks operate once. And in that little blue-gray car, we purposely pulled out the cylinders that were in the original patent vehicle, they were purchased in 1979 and one of the cylinders purchased in 1979 was this one and when I was mounting the spool valve on top and I had a jam nut on here to hold the plate steel that held the spool valve while I was tightening this thing up, I rotated it and then it leaked and the engineers thought that I might be able to put a center punch mark on it, you know, to keep it from rotating, but it didn't work.

Uh, Toby Called Bimba and the next morning, we had a brand new cylinder. We get anything we want, but we're not greedy.

We've got some international sponsors that are sitting back waiting to see what the government and the energy dept. tell us, you see. They're sitting back and waiting.

Now granted, if I call Bimba right now and said that I need five sets of, you know, well if I had five cars I wanted, they'd give us the cylinders, they're just waiting to see what's going to happen. Ingersoll-Rand is waiting, Comdyne is waiting. They're international manufacturers, they want to see if the standard line is going to persist or we're going to get a little help. Okay.

The other car has the cylinders from the blue-gray car in it and we can disconnect the four inch bore cylinder completely or we can just disconnect the hose, and we can open the re-use tank, the valve where it goes ahead and plumbs the air into the re-use tank but we just blow it out to the atmosphere and then we can drag that four inch cylinder, it doesn't take much of anything to do it. Or we can disconnect the tank completely and we can drive the Chevrolet Sprint around the racetrack on one cylinder. And here's what will happen.

We fill up three scuba tanks with, roughly eighty cubic feet of air each, and these people have been to school, we drive the car on the one cylinder, now what determines how much air you use?

If you go down the road, two things, the pressure that you put into this cylinder times the gear ratio determines how much air you're gonna use. If your gear ratio gets 28 1/2 feet**(Correction: 38 1/2 feet)** down the road every time this cylinder goes "choo-choo", if that hadn't given you enough power to drive the car with which I've done before,uh, you're gonna use a lot less air. Now with this car, every time you move 11 feet, you're gonna, you're gonna take in alright we set the pressure at, let's get right down to graphics, we set the pressure at 250 lbs and if you hear the safety valve go pop,pop,pop,pop,pop, that means you're a little too much pressure and you back the regulator back, you know. Alright.

But we run at maximum pressure and that's about all this cylinder can do , to drag a person around the racetrack at National Muffler Shop and at 250 lbs of pressure, you get about 5 laps around the track. Alright.

Then when you save and re-use the air, and you put it in the next larger bore cylinder, you are able to back the pressure back to about 165 or if you want to be a little risky, 180 you ride the brake a little bit, you'll end up going about 9 laps around the track. Uh, no smoke and mirrors, it's demonstratable and of course then after going around the track in these two cars, when you get in the " Spirit Of Joplin" car that's got four cranks working for you, you'llnotice we have a bumpy ride because we have a lousy suspension system on the car,uh, you'll notice it's a pretty smooth ride.

Okay, I want to go through the steps of discovery and tell you exactly how we figured this out and the way to do that would be to give you a copy of the line drawing of the engine and I'll put a copy up and, and ,uh.

Now, for the students in class, I usually go ahead and draw this all out, but I'm sure that this is going to be something that will work out alright.

Now, the configuration of the patent vehicle was a tricycle and I'll admit at this time that when the gear ratio was figured out, it was a copy of a wind-up train.

The big gear here has roughly 270 teeth and I spent probably well I had at least three, four hundred phone bills even calling Europe to find out if there was anybody whou could make me a spring 3/16 inches thick three inches wide that we could put in a jig in the garage at night and with a small sewing machine motor and two or three gear reducers, we could slowly wind this spring up with the idea of getting maybe a 10 or 11 mile range out of a wind-up vehicle. It was something to play with.

I'm an aircraft mechanic,uh, last as an aircraft electrician. I know a lot about air, but I didn't know much about springs at the time.

Here's what I did. We hooked up this very cylinder which is an eight inch stroke, four inch crank turning this big gear, we put a T-size cylinder of air on the vehicle,set the regulator to 250 because they said that that's what the working pressure was and we'd drive from Riverton, Ks. to the four-way stop at Riverton and we could turn right and go about two more blocks before we had exhausted all our air.**(Note: 6.2 miles)**

We did this about three times to be sure that was right and the exhaust noise, we used a little plate Bimba valve which was a little bitty rotary valve at the time and I operated that little bitty valve with a spring push-rod ,uh, type of arrangement where by the little bitty Bimba cylinder valve I think that we paid about $23.00 for it at the time, it wasn't a spool valve but the exhaust noise was LOUD!

It was obvious that at 250 lbs of pressure that we were wasting air that's for sure.

When you cranked the car back to 150 lbs of pressure, there was about three hills it wouldn't pull because, after all, we were in high gear.

Okay, so we put this tank on the car and it's just an air-up tank and I put a gauge on it and a ball valve to relieve pressure. Of course it had the safety valve that would pop and I set the safety valve at about 180 lbs of pressure and we drove the car,uh, but before we could save the air, we went to a spool valve and with tapped exhaust ports, I didn't know, we went to tapped exhaust ports and we saved the air and put it in the tank.

Some interesting things happened that there really isn't any reason for anyone to think about it and if they are going about designing something but when, when we get up to about 100 lbs of air pressure in the tank, the,this little old trike would just slow down and didn't want to go anywhere but it would still move. And all that drag all that wasted energy right, that's what I thought, maybe maybe all that energy is wasted.

We're saving that exhaust and putting it into the tank and finally when you get up to about 140 lbs of pressure that meant that if we had 250 on this side, 140 on this, we were just down to where we had only had 90 lbs of pressure to drive the car and it would just come to a stop.

Right then we'd bleed this pressure back down to zero or sometimes before we ever got down to 40 or 50 the car would start moving again because we had relieved the back pressure.

Okay, so three hills I pushed the car over, I got out and steered with the tiller and pushed the vehicle over the hill, you know. I wanted it to work, I wanted it to strain to get there. I'll tell you how far we got with all this drag you know , all this friction, we got to Riverton turned the corner and went two blocks on a T-sized cylinder of air.**(Note: 6.2 miles)**

We repeated this experiment twice. Then it became obvious that the back pressure was killing us, and we put air into this tank as soon as the back pressure got up to where it was equal or balanced out with what we could put in the car, the car stopped, that's natural.

But how? How to do it? I ordered two things that day, ordered three. I called Bimba, no, I called the distributor, we weren't on a first, we weren't that close to Bimba like we are now. I called the distributor in Kansas City. I ordered a four inch bore cylinder, bigger, I ordered a spool valve, just like this. One that was cam-operated and I got in touch, I went to the farm store over in Carthage and found a pig drinking valve. All this pig drinking valve here is a lever operated non-pressure sensitive vent to the atmosphere.

It could have 500 lbs of pressure on it which it has, it could have 50 lbs of air pressure which it has and to bleed off to the atmosphere all you have to do is to move the lever over. But when you change the pressure, it didn't bother a thing. So while I was waiting for these parts to come in, we designed another cam with a skate wheel from the roller skating rink, and two of pillow block bushings and a piece of shaft material to push on the roller on the cam to time our spool valve.

And this spool valve ran right down out of the car to what eventually turned out to be a couple mufflers because we drove this car indoors quite a lot at shows.

Okay, we set up this vehicle and ,uh, the next time we drove it, we were re-using the air and but I didn't have a cam rigged up to the pig valve so I had a young man by the name of Tony Tripoli, who worked for me in the camper business over in Crestline, drive the car.

We set the air pressure at 250 and I layed down on the floorboard of the car and I had a little lever and I watched the cam and every time the cam would come up to the point where it was able to deliver its' maximum power, you know, not top-dead center, but in the center third, I'd lay on the pig valve and it would go "pssst,pssst" and this was very haphazard but it worked and I was able to maintain,uh, was able to pump this tank up to where the safety valve would pop at 180 lbs of pressure.

Yet the car would would still move down the road because every time the number one cylinder got to where it needed to deliver some push, you know, some power, I'd be bleeding off the back pressure that was killing me.

Alright, how far did we get down the road? We didn't get to the four-way stop, we got down to Leon King's place, which I'd say we were hurt, probably about four blocks in total distance traveled.

But I was able to put air in the tank and I sometimes, I got worried about the safety valve blowing off and we'd stop the car and open the ball valve and bleed it back down to 80-60 lbs and start again.

So we figured out then the next thing to do was to rig up a little model airplane wheel on another little cam located on the side in a bell crank so everytime you got to top your maximum point of power you'd bleed off your back pressure.

So we had figured out a way to save and re-use the air! So, the next time we we hooked up saving and we hooked up the cylinder to where we could come out of the cylinder and down and into the spool valve and we were actually re-using the air, I'm sorry, if I said we were re-using it before, we weren't, we drove it just with the pig valve just to see if we could save the air here.

Okay, then when we hooked up the cylinder the first time we drove the car with the pig valve operating, we drove to Riverton, we hung a right and went two blocks, went clear down adross the railroad tracks across the river and up in to the high school parking lot at Baxter Springs.

We went,uh, about 11 and 7/10 miles, re-using the air, yeah, I was ecstatic and what it boiled down to is we determined that if we could could use the air more than one time, we could get the power we needed, we could get the energy efficiency we needed and come up with a vehicle that we could drive on the street.

And believe me, it can be done.

Now we also determined that sometimes during the driving of this car if you were to, if you set your pressure back say to 200 lbs and drove the car re-using the air, it would clip along pretty good and you'd say well if I put in 250 lbs, I'm gonna be using more air, but that's when we discovered the equivalent, what is equivalent to the point of non-productivity, in other words we crank in 250 to about 225 lbs of pressure the car would move faster and we seemed to have more power and ,uh, due to the fact that the cylinder was operating faster it simply couldn't vent and port the air and that was alright.

Then when we went on up to 250 lbs we could find that the point at which the cylinder just couldn't operate that fast and we were into the point of non-productivity.

Uh, if you allow time for this engine to work, if you save and re-use the Kinetic energy, you can get out of the vehicle a lot or most of the energy you put into it.

Uh, now the comparisons with CNG and the comparisons with battery cars we can make.uh, and I hope to ,uh, what it boils down to is the re-use of air. The re-use of air gives us an opportunity, well I'm gonna mention CNG and battery and I'm gonna mention gasoline at this time.

This is reasonable, this is reasonable assumption. Everybody knows that in a gasoline-powered vehicle, we don't burn all the gasoline, a lot of it gets blown out the tailpipe crudding up the air and we don't get the energy out of it. Let somebody come up with a way where they can take the exhaust that comes out of your engine of a gasoline-powered car and put it in another piston and re-ignite it and burn it again and then put it in another piston and re-ignite it and burn it again, put it in another piston and re-ignite it and burn it again and you'd have something that would resemble what we're doing.

On a battery car, let somebody figure out how to take the electrical energy that's going in to drive your battery-powered car and the heat that you feel on the electric motor that's driving the car and if you could take the electrons that go through that engine and cause heat and don't do any good or if you could take the electrons that aren't even used and tap them off and use them in another electric motor and then in some way figure out how to use the electrons in another electric motor, then you'd be doing something that sounded pretty good, and you'd be doing what we're doing.

We're re-using the air to get all the energy out of it. Uh, the CNG car for instance that runs on compressed natural gas, we feel that our system is totally marriageble with their system and I'll explain that later.

Alright, with a CNG car, if they could use the Kinetic energy that they pay, you see they have an air station, a gas station, just like we have an air station.

If they could use this energy, this Kinetic energy instead of just running it through a regulator and bleeding it down to four inches,uh, four ounces of pressure and driving their car on it, if in the process of stepping down, if they could simply have a little turbine wheel in their plumbing to run the generator or if they could go ahead and use our technology to help drive the car or drive something in that car, then they'd have a hybrid vehicle and all the money that they're spending to compress natural gas for energy they'd be able to get some of it back but they're completely ignoring that.

And I think that for a hybrid vehicle purpose, it would be possible to go ahead and use,uh, this technology because we have driven this car on CNG,uh, I took it to Tulsa, I took it to Oklahoma City, They didn't have any air stations there, so we went ahead and ran the exhaust out the tailpipe so we wouldn't have the stink up front. It drives fine except for one thing, your your natural gas seems to act like a refrigerant and it doesn't take long to fog up your regulator and everything else because it really, when you drop the pressure of natural gas, I don't know why, but it really gets cold. Uh, when we drop the air temp of air and when we use it then we got our air-conditioning right there.

Uh, so steps to discovery. We found out that we can re-use the air. Let me take a minute here and the blue-gray car is one where we can clearly demonstrate this to you, not only that but we can, we can hook up the pig valve to bleed. Now for our production car and one thing we do not have hooked up on on this car, we do not have any midstroke venting hooked up on this car,uh if we do, it would give us a little more speed. It cuts down on your range just a little bit but if you hook up mid-stroke venting , you can go from the first cylinder and when you, when you do your mid-stroke venting, you can run that air over to your ,uh, the number two re-use tank cause you won't really have enough back pressure there to hurt you. And then for your mid-stroke venting for number two cylinder, you can go to number four cylinder's re-use tank.

And then the other two cylinders after that you can just vent them to the atmosphere. But from what my calculations and figures show, anytime you utilize mid-stroke venting you're going to cut your range down by about ten percent.

Uh, I would estimate that for an urban commuter in town, you you'd switch on your mid-stroke venting solenoids so you could have a solenoid on each one of your manifolds in lieu of a pig valve just an electric solenoid switch on your solenoids and you would increase the power of your engines like for passing or for something like that.

Are there any questions?"

Ralph Fleming: " Well I think uh as far as your discussion I don't have any but uh I will have some later when we actually look at the cars."

Terry Miller: "That'd be great."

Ralph Fleming: " And you demonstrate them. I would like to ask, uh, you said you drove one to Tulsa?"

Terry Miller: " We towed it to Tulsa, we didn't drive it. Let me correct that for the record, uh, the reason I towed the car around,uh, is that we were denied access to the Topeka Alternative Fuel Rally. Uh, we were denied access because we didn't act in a gentlemanly manner the last time we were there, which was two years ago. Uh, we were denied access because we moved our car from the position assigned to us.

Then the next time the media checked and asked them, we were denied access because we weren't an alternative fuel vehicle and the next time we checked with them, we were denied access because the round-up committee had got together and had determined that since we weren't recognized by the U. S. Energy Dept. as an alternative fuel vehicle and we didn't get to enter.

So,uh, we put a tow bar on that little "Spirit of Joplin" car and I filled it up with air and I hauled it to Topeka and I demonstrated the car to the *Topeka Capitol-Journal* newspaper and I told them what the problem was and I said did you know that,since 1983, the U. S. government has been selling the building instructions to this invention to anybody in the world that wants them and they've got the guts to turn around and tell us that, that up, that uh, Benjamin Watson with the U. S. Energy Dept. and the Kansas Corporation Commission, has told us that we can't enter this alternative fuel vehicle round-up because we didn't burn any fuel.

And it was ridiculous and the T.V. and I drove the car for all three T. V. stations, uh , while I was in Topeka.

And when we got down to the fact that I was out of air and I still wanted to drive it and demonstrate in Topeka, then I just aired, I just gassed the car up at the at the CNG station in Topeka. There's only one, it's right next to the Courthouse in Topeka.

So, even after all the publicity and and fussing with the Energy Dept. was over, I was able to drive it in Topeka cause I had used, I had to buy the gas, but all we did was drive on the Kinetic energy of it you see."

Ralph Fleming: " You didn't burn it, used it just like it was compressed air?"

Terry Miller: " Right, cause and it's very, it's not very good at all to use because it has a freon type effect.

When you decrease the pressure, it really frosts up bad. For demonstration, but Toby Butterfield was right, it does cloud the issue a little bit because I took the car to Tulsa and drove it on CNG and demonstrated it for the media where the Spirit of Joplin car then I took it to Oklahoma City and the reporter there,uh, interviewed me with the car and I took her for a ride and the T. V. camera showed up and I had the car on jacks and running and the reporter told the,uh, her editor that the car, that I was running it on CNG and they banned it, they wouldn't none of the T. V. stations or anything would do a story and so Mr. Toby Butterfield was right, it was clouding the issue, people thought we were like a con man, we were there running a car on natural gas.

And the truth of the matter is you see, the patent vehicle was demonstrated from coast-to-coast in major cities,uh, in '82 and '81 and '82 and on national T.V. and all,uh, that's no problem getting publicity.

But the kind of publicity where it says, he says this will do this and he says that'll do that doesn't count you know.

But we're getting published by some reputable engineering magazines now and that helps.

Uh, back to the CNG part and back to the towing part, we did not drive the car to the, these cities, we towed it there, but we did get into the show in Topeka a year ago, since now they've cancelled the show there is no more.

And we were the hit of the show, we put the car on jacks, we found an air station three blocks from where I was set up and it was a fire station and they used their breathing air, scuba gear, Forbes Field, yeah, they gave us a complete air up anytime, we'd air up, well we aired up two times while we were there and and all we had in were just little old scuba tanks. We only had 600 cubic feet of air on board.

And we were the hit of the show, we,uh, sold video tapes and handed out literature and picked up some club members, and had a pretty good time demonstrating.

But being able to teach the technology has given us more credibility than anything.

Because the way I feel is the Energy Dept. can take these tapes and take anything that I'm teaching and and publicly prove it's wrong, prove it to us first.

Alright, this public damnification of our technology that's been going on and off and on by the Energy Dept. is deplorable, and that's why you're here.

John J. Brogan told me that if the fellow with the Hybrid Motor Vehicle Division of the U.S. Dept. of Energy did what we say he did, and what was published in the Ottawa News and the Associated Press world-wide was a deplorable thing to do and in violation of Energy Dept. standards, and maybe I've answered too much of your question but we'll go on.

We feel like we've been shot at and missed and crapped at and hit in a way, but we realize why, because the standard line of the U. S. Energy Dept. has been " it won't work, anybody wants to run a car on air has got to be a kook." and they were right if they looked back on the existing patents, you see."

Ralph Fleming: "You can't get enough air to go anywhere."

Terry Miller: "Yeah, you couldn't get enough air to go anywhere and all that sort of stuff."

Ralph Fleming: " You say you got some demonstrator cars?"

Terry Miller: " Uh, huh."

Ralph Fleming: " What is the maximum range you're able to get and at what speed?"

Terry Miller: " We'll demonstrate to you and you can draw your conclusions and write down what you want to write down and we'll be happy with what you determine is that fair enough?"

Ralph Fleming: " Right, okay."

Terry Miller: "The immediate goals of what we're trying to do,uh, the immediate goals ,uh, that bearing in mind that we have time to consider that it takes a certain amount of time,uh, to do the work that we need to do our immediate goals is to come up with a transmission for the vehicle, uh, and,uh, several transmissions, and possibly a variable speed transmission because, uh, the speed right now which we would call the point of non-productivity, in other words, if you run the engine faster than 40 RPM's you're putting more air pressure in than you can vent and port in a reasonable length of time, which doesn't rob you of anything, but you're just using extra cubic inches of air.

This isn't a smoke and mirror thing that we need to overcome, this is factual and we know we can overcome this by changing our gear ratio. What we intend to do on the Spirit of Joplin car right now, we have a 140 tooth gear driving a 20 tooth gear. What we intend to do is to,uh, put a transmission out here with ,uh, a 40 tooth gear driving another 20 tooth gear, in other words, we want to change our ratio on the transmission which is the cheapest thing we can do,uh, and to change from one gives you,uh, seven to one equals 14 which means that instead of going 38 1/2 feet down the road, we'll be up into the 75 feet down the road.

Uh, the ,uh, timing,uh is really, I don't really consider the timing as important as the, as the transmission,uh, the ,uh, motor frames for our production car,uh, everybody looks at our motor frames and they and the engineers, and we have an engineering firm called,uh, Technical Engineering and Sales and they have done probably $8,000 work for us here in Joplin just on gratis just for because they want their foot in the door and they're very good sponsors.

And what we intend to do in a production vehicle is to build motor frames which are also the re-use tanks to re-use the air. We intend to build these motor frames ,uh, out of stainless and use the ,uh, roller bearings which from what I understand, we get,uh, have more power out of an engine if we use roller bearings, and,uh, we've got engineering drawings made up for the vehicle,uh, but right now we are into retrofit and our immediate goals is to manufacture engines that will fit in Toyota Tercel, The small Volkswagen,,uh, the Chevy Sprint, The Ford Festiva, your small front wheel-drive vehicles that,uh, that have a,uh, empty weight of 2300 lbs or less. so by getting into the retrofit market, we're not sure yet, we haven't heard back from California, from the air resources board, but we need to find out if the retrofit vehicles will, will buy into this share selling project that they have out there, in other words, if General Motors is, say manufacturing cars, and they don't want to manufacture any zero emission vehicles and they can get us to make some, then they can buy their shares of what they're supposed to produce in California. And we haven't heard back from them yet anyway. Yes, Toby?"

Toby Butterfield: "I think that they call them credits."

Terry Miller: " Yeah, that's right, credits , so,uh, in some states, there's three that have mandated zero emission vehicle laws, but for people look at this engine with a oil-lite bearings that we have in the engine,uh, the the,uh, people say well this engine will last forever,uh, because at 40-50 RPM, it is a pretty long life engine with needle bearings on the rod ends and ,uh, and roller bearings in our motor frames we've come up with an engine that will last a long while.

Uh, we're not going to get so much into the finances of it right now but what we want to do ,uh, how do we want to get in the ,uh, pneumatic Urban Commuter business is to,uh, go ahead and come up with a transmission we need and come up with,uh, motor frames that are easily steam cleanable and,uh, Bimba is willing to work with us to come up with the cylinder whereby the spool valve can be set on it and taken off-also the fact that the most all this stuff is out in the open and easy to maintain we hope to ,uh, get back into position where ,uh,uh,uh, fellow with a little bit of mechanical efficiency, mechanical inclination at all can change some parts on his own car where there's not much anybody can work on the new cars that are coming out unless they have special equipment.

But the main thing we do have,uh, is the ability to go ahead and design,uh, engines that can be put into a car. and one thing we've had to overcome is the fact that there's a tremendous amount of brute force in the,uh, in the engine and we had a problem with twisting the crankshafts right out of the gear, but we have a system now where we can put a keyway and press it in and they they're staying in and your drive, your, your crankcase gear or your crankshaft gear,uh, some people call it the flywheel but it can't be at 40 RPM's but they call it a flywheel anyway this ,uh, this gear,uh,can ,uh, have the different, we casn have different teeth configurations, but right now we're at 8 diametrical pitch, 14 degree pitch angle and ,uh, to ,uh, for the constraint of the size that we have in the car this is about the longest,uh, we can go to a 12-inch stroke,uh, cylinders and we need to ,uh, to ,uh , acquire more funding to go ahead and develop a prototype production engine.

Now we're not talking building a whole new car cause I guess you can get into three or four billion dollars to develop a whole new car.

But we would like to have some assistance to teach this technology around the world and assistance to teach this technology in other cars,uh, to other in colleges and other states in the union.

Uh, the nomenclature of the engine let me give you a copy there and I'll put it up and we'll see if we can't name the go through I'll go through the parts and name all the parts real quick. And then we'll go through some operations,uh, the cylinder the first cylinder use air is the second one across, its a 2 inch bore cylinder.

Here's the steel frame here that's welded to a plate and then the spool valve bolts to that plate,uh, there's a front mount bracket here that's threaded in the jam nut that tightens that up and the spool valve literally sets astride the cylinder just like a saddle on a horse and you can see the the shaft coming out of the spool valve and the set collars.

Here's another real good picture of the striker,uh, we're combining a lot of different things in timing, I mean you're gonna call it push rod? You're gonna call it a rocker? A rocker? You gonna call it a cam? And since it really doesn't equate too much ,uh, with ,uh, reciprocating gasoline engines we just simply call this rod the timing rod.

Uh, we call,uh, the set collars the stops and we call the vertical piece,uh, of 3/8 inch steel tubing with a nut welded on the end, the part that actually hits the,uh, top dead center and bottom dead center, the part that actually hits the timing rod we call that the striker.

So timing rod, uh, adjustable collars for timing and your striker. And so we'll get back to the number one cylinder then we have a hose coming out of the firewall on the car from the regulator and it's a high pressure hose,uh, and it can be disconnected from the spool valve here for maintenance or getting into it and we,uh, our regulator has a stop on it to a maximum of 500 PSI to this cylinder and the spool valve instead of being a 1/2 inch port is 1/4 inch ports.

And this spool valve operates to this cylinder which is drivingly connected to the crankshaft gear which is which meshes with the 20 tooth gear at the bottom of the motorframe to turn the left axle of the car and the exhaust air from this spool valve via the manifold ,uh, goes into the motor frame of the left engine and then we take air out of this motorframe to the spool valve for the next cylinder which is the farthest one to the left and it's a 2 1/2-inch bore cylinder.

Now the manifold which does this if we plumbed into the exhaust here before it goes into this tank right here and we put an electric solenoid valve there to port our mid-stroke venting then the complete nomenclature of the manifold and the way it works is pretty simple to explain,uh, the air that's used in this cylinder the second cylinder to use air which is 2 1/2-inch bore the exhaust air comes over and goes into the motorframe and,uh, the nomenclature then is the motorframe for the right engine, and the air comes out of this motor frame and is used to supply the Kinetic energy air to number three cylinder, double-acting cylinder.

Then the air exhaust air from number three cylinder goes to another motor frame ,uh, which is really just a tank but it's made out of the same material as the motor frame is made out of, it goes across from wheel-well to wheel-well underneath the engine and,uh, the exhaust air from this number three cylinder goes into that tank and you draw out that kinetic energy to use for the 4-inch bore cylinder which is the last cylinder to use air.

Now the manifolding if we use,uh,uh, the ,uh, bleeds to increase our power of our engine has a name and the name describes,uh, the air flow and then what's happening if,uh, the uh, exhaust manifold from the spool valve if the area here is that I'm circling. Uh, if this is your spool valve and this is your exhaust air, you can take your exhaust air and put into a tank and at the other end of your manifold, you can have your bleed valve. Now, in the process of operating the engine when the cylinder is in the mid-stroke position, and the piston is in a 10 inch stroke say when you're in here about 3 inches in the center, and you've got about 3 1/2 inches on one side and 3 1/2 inches on the other, but in the center 3 inches is when this crank will be OUT of the opposite of top dead center, it will be in the position to deliver the maximum force that you can get.

During this time is when you want to vent your exhaust air coming out of this cylinder and going to your spool valve is when you want, instead of putting the air through a check valve and into your re-use motor frame section here to save and re-use the air you,uh, energize a solenoid valve and you vent that air to the atmosphere which is the same basically,uh, basic concept that was used, same technique that was used with the pig valve in the vehicles that you'll be able to drive.

Okay, the action here has a name and the name denotes what's going on. During the first portion of your stroke and the spool valve has changed over and your venting and your porting of pressure has changed and reversed your air that's clearing out of your cylinder having been used to drive the cylinder one way is allowed to expand out of your cylinder through your spool valve and into a re-use tank which is a motor frame.

So the first third of this stroke is called the pressure equalization transfer portion of the stroke meaning that your Kinetic energy is allowed through pressure equalization to expand into your re-use tank.

The center third of your stroke is the portion where you have your venting or in this case we call it mid-stroke venting, now during the last portion of your stroke, and if you'll look at this drawing right here, you'll see if this gear is turning this way and and this from top dead center and down from this to top dead center, you've got this much rotation, say maybe 25 degrees of rotation right now your pressure on this cylinder pushing it it is a push direction or at the back of the piston it's not really imparting much torque to the wheels of the car but the sheer force of the vehicle rolling down the road being driven by the other cylinders is more than enough to go ahead and cram this piston right on home and it will literally pump all the rest of this air that's in that piston into the re-use tank.

Alright, the name of the total process is called manifold sixteen and it's the pressure equalization transfer mid-stroke venting pumped pressure transfer manifold and the pressure equalization transfer mid-stroke venting pumped pressure transfer manifold describes exactly what the manifold does.

Now if you don't bleed off your back pressure, you can't get the full power out of the engine. so bleeding off your back pressure is one way to get a little bit faster engine and this can be demonstrated in our blue-gray Chevy Sprint. It cuts a little bit down on your range, but it will give you more power.

Okay, now at the time this was figured out the time this was worked out,uh, the man that did this and developed this technology had no idea how well Volclan's steam engine, his compound steam engine worked.

Alright, you take a small cylinder on a steam engine with big old sliding valves adjacent and a great big huge cylinder tied to that and there was practically no limit to how fast this cylinder could work on a steam engine.

You had steam, super-heated steam in here driving a piston driving the wheels of the locomotive and steam has a continually expanding nature that air just doesn't have.

And the air, when you open up these great big ports and vent this steam from one cylinder to another, man, it would just run away.

Some of your best speed records were set by steam engines.

Alright, if if you look at the way that Volclan's patent and his invention worked for the compound steam engine, you'd look at this and you'd realize that there's no way in the world that you could do this with air because it's obvious that if you did that with air, the back pressure would kill you.

And I was, we were very fortunate that we didn't know how compound steam engines worked at the time that we came up with this.

Uh, let's go on, we've got the air all the way through all the cylinders everytime the crankshaft gear goes around one time, the car goes 38 1/2 feet down the road,but in driving the car, you can hear two exhaust noises every time your spool valve operates and for every two exhaust noises that's one RPM, so you'll be able to count the RPM's of the vehicle.

Uh, on the rest of your engine parts,uh, nomenclature,uh, I think that we've just about covered the names of every part and every part on the engine.

So the next thing is a comparison of our technology with other existing technologies and,uh, by comparing the technololgy you figure out do we have advantages do we not have any advantages and so on but we'll first thing we'll get into right off the bat is type or on-board storage that we have. We have,uh, aluminum tanks which are carbon fiber wrapped supplied by Comdyne ,uh, and evertually we'll have all carbon fiber tanks.

But right now we only have one exclusive carbon fiber tank and it's on top of the vehicle. The nice thing about these tanks due to their light weight is that we can have a four passenger air-powered vehicle because it's possible to put,uh, three tanks on top of the car because the car, the tank we have on top of the car now only weighs 100 lbs.

Uh, I understand from what my figuring and my checking, if that tank were steel, it would weigh like 200, excuse me, about 465 lbs or in other words with heavy weight steel tanks on the car for one thing they'd smash your roof in and two you couldn't go around the corner without the tanks flipping the car over.

So, we have an,uh, advantage of having light weight air storage capability on top of the car because our tanks are so light.

Now the,uh cubic foot of the tanks adds up about like this. We have two tanks in the car which filled up to capacity hold approximately 625 cubic feet each and we have a tank on the roof which holds 615 from the ratings we've come up with so we'll figure it out. 5,6,1220"

Ralph Fleming: " Is that 815 cubic feet?"

Terry Miller: "Yes, 815 cubic feet.

Alright, roughly 2000 cubic feet, now how much is useful? Alright, take,uh, we usually stop driving the car at 500 lbs pressure that way you're always ,you know we head if we're not at the air station, we get back there by the time we've got, one thing about this car you can look at your air guage on your regulator and you can tell how much more energy you got left to drive on. Alright.

Back at 500 lbs of pressure, since we come now, 500 lbs of air pressure in your tanks holds a lot more cubic feet of air in that 500 lbs than you'll have in the next thousand lbs of pressure but for all practical purposes, we take a 6th off of that so,uh, a 6th of 500 or let's just say well let's just do it, let's just divide it outhere and s see, 1/6 into this, Alright, let's take about 350, let's take your 2065 and subtract about 344 cubic feet from it so every time we air up we put approximately a 1000 if we air up at 500 PSI which is what we're gonna do,we're gonna do that, uh, you can figure we're putting 1721 cubic feet of air in the car,uh, we won't go to over-fill, we'll just, we can air up to 30,uh,...3000 plus 10% over-fill but we'll just air it up to 3 thousand lbs of pressure so,uh, when you figure out the mathematics of it, we'll have about 1700 cu. ft. of air in the car.

Then we'll be able to drive the car, see how long it will drive and the performance we get out of it.

While at the same time, uh, we can drive the other cars and then also we'll be able to power up the air compressor and see how much natural gas it takes to go ahead and fill the car up.

So on the rest of our on-board storage,uh, each tank has its own individual on/off valve so when we shut down for the day we can safety it up.

There's a regulator located between the seats on all three cars to control the pressure that you're using for driving, all the tanks we use in the cars are DOT approved,Department of Transportation, tanks and they all have to be hydrostatically tested,uh, the safety and the technology of the on-board tanks,is the same as CNG in other words, we have the very good benefit of the fact that we have CNG people over the nation,uh, figuring out how to cram compressed natural gas into a car and that helps us because if they can figure out a way to cram in more CNG then that will also be figuring out a way for us to cram in more air.

So we have the usable air, and you have your record, I mean you'll have a record of it."

Ralph Fleming: "Do you mean the actual internal volume of those tanks?"

Terry Miller: "Uh, you mean water?"

Ralph Fleming: "Yes."

Terry Miller: "No, but I can get it for you. If you, right now you've asked me for it and we'll get it for you."

Ralph Fleming: " Yeah, I'd like to have it."

Terry Miller: " Yeah. And the internal volume in water. No problem, we can get that, yup. Uh, that's something ,uh, you know what I worry about? I worry about what makes these work. I'm not an engineer and , yeah, we can find out by the time you get your transcript back. We can have that question answered for you. Uh, I know, I've been told what it was but,uh,uh, I've never cared,you know, because it hasn't been important to what we're doing."

Ralph Fleming: "Sure."

Terry Miller: "You see, okay. Uh, now,uh, we we figured,uh, the amount of air that we can carry and let's make some comparisons. Now CNG use and air use are ~~potable~~ comparable and we propose a marriage of the two technologies in any way possible and from what we got off to a shakey start with the CNG people in, in Kansas at the energy show, we feel that we're gonna develop a good working relationship with the CNG people here.

CNG does have a few drawbacks , but they're not really a,a drawback that I would want to make public ,uh, necessarily because we want to be compatible with CNG but from an engineering standpoint, I'd like to review something. Here, this is a a something that I read in the paper it says, "Natural gas-powered automobiles, are the energy and are they saving you energy and the environment?"

Texaco proudly proclaims this in a large city nearby, could it be corporate tokenism for image sake consider the requirements, these are the engineering requirements,uh, you know, what does it take?

First, coal is burned heating water to make steam, steam then turns a turbine, the turbine turns an electric generator to make electricity, electricity travels to the city by wire through transformers burning energy, this electric energy is then burned in an electric motor utilizing belts and pulleys that drive the natural gas compressor, compressing home heating type natural gas into,uh, compressed gas so it can be carried in gas cylinder tanks in the automobile.

Then the gas is also burned to power the automobile engine. Four energy burns are used, one for coal, two electricity and one natural gas.

Uh, as a means of comparison, we burn natural gas one time and we turn air like you and

I breathe into motive energy to power a car with and we think that's a step in the right direction.

Uh, another comparison is battery -powered vehicles.

Our vehicle weighs 1650 lbs . Another vehicle by the same manufacturer and supposedly the best leading air battery powered vehicle in the nation owned by a college sold by Solectra Corporation and batteried by Eagle-Picher weighs 3400 lbs.

The vehicle weighs twice what our vehicle weighs,uh, I don't know what the whole story is about energy density is, I don't know how they explain it,uh, unless they say that a battery takes up so much space and it will put out so much energy, but I think there ought to be a energy weight density, you see, uh, we compare real good when you, when you or I would imagine if you talked about energy weight density, uh, now a batteried powered car has,uh, certain things that we can compare to our technology and how do, how do air-powered cars compare to battery-powered cars.

Alright, If the daughter uses the electric car for afternoon shopping, well mom and dad find it plugged into the charger, not ready for a visit downtown. cold temperatures cut battery function on energy delivery by much yet a full energy charge is still needed using considerable amounts of real energy due to the energy burns and conversions.

The set-up is like this, a utility generates electricity with an energy burn of a non-renewable source, current flow in power lines and transformers burns more energy talking about Ohm's Law, then this AC current is converted or transformered down and rectified so that they can charge the batteries.

This direct current is then burned to charge the car's batteries to a ready state to energize the electric motor powering the car completing the last energy burn.

The battery process uses only five energy burns, two chemical conversions and and,uh, another,uh, energy,uh, process where by the AC ,uh, DC is turned to AC,uh, changed to AC.

We feel that there's not a great lot of enthusiasm for battery-powered cars because people demand utility in their vehicle they they they demand uh the utility of a vehicle if they're, if they're gonna drive it and to date we haven't found this in a battery-powered car.

The situation on air-conditioning, uh, on the vehicle, the exhaust air of this vehicle is cold, and the air conditioning is so simple, uh, battery powered vehicles are crying, trying to figure out a way where they can run their air conditioner without severely limiting the range of a battery-powered car.

Alright, here is your heater core, a little drawing of a heater core in your air-powered vehicle, your exhaust air comes out of the number four cylinder and it is cold, often it's cold enough to frost up the cylinder, uh, often three and four cylinder frosts up.

Okay, your air is cold, you don't want to run this air directly into the cabin, but in the process of of coming out of the car and venting the rest of your exhaust air to nature, all you need to do is to take a portion of this exhaust air and run it through the normal water filaments areas of your heater core and then go ahead and exhaust it so you've got two exhausts, you've got a portion of your exhaust going though your heater core and the rest of your exhaust going out the car.

It's air, okay, if it springs a leak inside the cabin, it's not gonna hurt anybody.

Okay. Now all you then is a regular fan that's in the car, just a small of the small electric motor that's in the car and when you want, when you want cooling you turn your valve to give you cool air and you turn the fan on and you've got air conditioning.

Now in the winter time, all you need is a toaster element in front of this core just to take the chill off the car and you've got heating and air conditioning.

It can be done and it, and it can be done with a minimum amount of electricity. Uh, uh, it works, we, we've you can feel the tail pipe on the car when the tail pipe was hooked up and you can feel the tail pipe and it's always cold.

You can feel the cylinders and it's just cold, it's really simple,uh, everybody's familiar with that it's no problem as pressure decreases, temperature decreases, see we get free air conditioning. Uh, that's no problem also you're exhaust air can also be used to turn a small turbine or a little fan to generate some electricity,uh, it won't be any problem from what the Crowder College tells us to put the solar panels on the roof to keep a battery charged for turn signals and stuff. There, that way you're not having to use any of the power of the engine to drive the car with.

Uh, in in the process of going from your,uh, high tank pressure, 3000, 2000, 1500, or a 1000, it would also be possible the same way that we are proposing that CNG use it, but some where in your high pressure line,uh, you could, you could have a small fan in here driving a little generator to generate some electricity. Uh, we don't see the need for electricity to be a problem. We would if our air conditioning had to depend on a large amount of electricity you see we eliminate the following things, we eliminate a compressor, we eliminate the freons and other gases that might be harmful to the environment, we eliminate the condenser, we eliminate all the ~~waste~~ weight of all these things too.

All we need is the heater core and we can use the exhaust air to cool the vehicle.

Now that's a selling point, another selling point or another advantage is that if you figure up the cost of of a conventional battery car like Solectra sells right now, they sell a battery car for $2600 with all the goodies on it, I'm sorry $26,000 with all the goodies on it, GEO Metro, and after hearing college students here on live T.V. and the professor say that the battery car will run for a penny a mile on electricity and hearing them say that it would go 70 miles at 70 miles an hour, when they first got it from Solectra .

I called Solectra and I asked them and they said this car will go, I said now I want to know,uh, you got brand new car, brand new batteries, fully charged, you're driving around in town, stop and go driving, ambient temperatures you know I said 72 ,uh, reference what is the best range we can expect with everything new.

The man who runs the company said 42 miles, we'll guarantee. And he said that's when everything's new.

I said alright, what's the best speed that the vehicle will go the one like you sold to the college. He said, on the freeway,level ground, no wind condition, everything right, 62 MPH after it's charged for the first five miles is the best we've ever done.

Now, we tell the truth and we're gonna tell you the truth of what our car will do, but we're gonna show you hopefully as an engineer that that gearing and a a little bit bigger engine and we have air conditioning we have other things but we feel that we deserve a leg up because we're on to a technology that offers something that a battery-powered car doesn't not offer and that's 100% utility!

You can drive the car this afternoon, Toby Butterfield can drive it this evening and your kids can take it out and drag Main Street tonight and Uncle Ben can borrow it to go down to Shoal Creek to go fishing, it's available 24 hours a day.

It doesn't take but very few minutes charge time and I'm sure we'll get that recorded and documented. We can demonstrate a charge time at seven minutes or we can demonstrate a charge time of four minutes.

If we utilize the cascade system of charge of refilling the car and we're not in a hurry, uh, seven minutes is adequate. If we want to draw off our two high pressure tanks, we can zap that baby full in four minutes. Uh, that's quick, there's no battery in the world that will do that.

We need improvements in,uh,uh, from the tanks we need improvements in manifolding and regulating the air that goes to the engine, the air conditioning,uh, I repeat it's simple.

Built in storage, the big three auto makers claim that they're over there working toward built-in storage for CNG and boy we, we'd give them all of that we're tickled to death to see them do it, however I think they're I don't know it just seems hard if you can build a rectangular tank or any other shape other than round that would withstand ,uh, three,uh, four thousand lbs of pressure.

Now, the advantage that we have over,uh, our storage facilities in Joplin, Mo. right now, we have 30,000 cubic feet of air storage, Kinetic energy ready to use.

Now if we blow a safety valve on one of our tanks,if ,if say we air it up to 4200 lbs and go home and the next day the sun heats the air up to 4,400 and the safety valve blows, and we lose all our air, what have we lost?

All we've lost is the energy that was used to compress that air which is not much.

We can put our storage facilities for air indoors. We can put it right indoors. We can have the compressor semi-indoors and outdoors. so we can close the door off in the winter time so the compressor won't be too cold or we can open it in the summer for ventilation and if we spring a leak, we won't blow a building up.

If we spring a leak, we won't have the neighbors complaining about the stink. There's a CNG station in Topeka, Kansas right now who and the people in the courthouse next door are all the time complaining about the fact that that the natural gas has a smell to it.

We , we think,uh,uh, to drive ,uh,uh, air-powered vehicle into your garage at home for the night is,uh, pretty safe.

But we're not going to publicly bad mouth CNG, we just want to bring out the comparison of the twol A lot of people don't like,uh, we have friends in Tulsa, Oklahoma who have been in the CNG business retrofitting cars to run on CNG and the lady told me that in the last four years, they've only had three people come in off the street and have their vehicles converted to CNG.

Now that doesn't speak much for the commercial viability of individual,uh, public people wanting to buy CNG cars and everybody we've talked to about battery cars, they don't want a car they can't drive all day.

So I want to repeat when comparing our technology to battery and CNG cars, we have the only technology immediately available, not like Chrysler, they're gonna have something in four years, our technology is immediately available providing a zero emission vehicle that you can drive all day long, and you can't do that with a battery car, you can do it with a CNG car.

Uh, but not with a battery car, and I understand the U.S. Energy Dept. is spending 43 million dollars this year, shelling it out to colleges and teaching institutions and battery manufacturers to develop, what kind of battery is it Mr. Butterfield, a breakthrough battery?

And what does Eagle-Picher say about the possibility of a breakthrough battery?"

Toby Butterfield: " Far away!"

Terry Miller: "They're the leading battery battery manufacturer in the nation and do they have a breakthrough battery?"

Toby Butterfield: "No."

Terry Miller: " They don't. Okay,uh, so we think our technology has something to offer and we're not looking for,uh, we believe that with our technology it's possible,uh, we feel that we've attained 60% of our goal and and our goal is a 200 mile range vehicle with a top speed, emergency speed of 55 MPH and we believe that that this is attainable and we don't feel that there's anything,uh, needed except some engineers going to work and a few fax machines put into operation."

Toby Butterfield: "More of the right cylinders and gearing improvements."

Terry Miller: "You see, you see it would be very nice if we just had,uh, could do what the Wright Brothers did if we could set up a flow bench, we might find that one cylinder needs to be 2 inch bore, and the other one,uh, 3 and 5/8 and,uh, we need this type of engineering and technical help, but if we take into consideration that you need the time to make this work, also porting and the venting of an engine, if we get away from 90's and T's that we have to use and get into ,uh, stainless steel manifolds that are stamped out and tig-welded together with smooth, smooth porting and venting, then perhaps our point of non-productivity could be increased up to maybe even 50 RPM, where we could be clipping along at 50 and and because we had smoother air flow we'd have time to go ahead and use the air efficiently.

Uh, there isn't anybody who can stand toes to toes and nose to nose, with us and these cars and and,uh, say that by the time that you figure up, now I'll give you the readings on natural gas so we'll have them as a matter of record,uh, if you, if we go out and fire up the air compressor to recompress air at,uh, with the current belt size that the air compressor has, we'll find out that the that the engine will use approximately 280 cubic feet of air per hour, while it's running."

Ralph Fleming: " This is ,uh, natural gas?"

Terry Miller: " You bet. This is an Oldsmobile,uh, 455 V-8 engine and while it is driving the air compressor, it will be and it will be running at;uh, approximately 1150 RPM, we have a tachometer on it.

And we'll be able to measure pulley sizes out there, and I don't understand fully exactly why this happens, but I can take a tach reading on the engine and get 1150, I can take a reading on the air compressor and get 900 but yet when you figure the the belt sizes and the pulley sizes, you'll be 150 RPM off and I, I'm not an engineer, I don't even try to figure that out.

Okay, we're going to get into the air station right now, that'll be quick.

Okay, oh one more thing before we get into the air station.

If you have,uh, air-powered vehicle, it's possible to sheet the whole bottom of the car.

We can dope and fabric from the bumper to the rear end , in fact, the "Spirit of Joplin" has a sheet of plywood under a portion of the car.

We can sheet the whole bottom of the car, so that there isn't any air flow restriction on under it and just have cut outs for the four wheels.

You can't do that with a battery car because somebody's going to get overcome by battery fumes, you can't do that with ,uh, with any reciprocating burning fuel like gasoline or diesel or anything because you'd have a hot tail pipe enclosed in all this mess or, if it was under the car, it would burn the skin.

In other words, we can sheet the bottom of a car and, and there isn't any vehicle that I know of that you can sheet the whole bottom of the car, which adds to your performance of the vehicle.

Alright, back to our air station. We have a V-8, 455 cubic inch Oldsmobile engine and this V-8 engine drives an Ingersoll, Ingersoll- Rand 15T4, 4-stage air compressor.

Now the accessories that we have on this ,uh, V-8 engine include two starters, and three batteries, because the belts are hooked up to the air compressor and we found it's a lot easier to kick both starters on and get your natural gas adjusted and get it running then we also have two bleeds on the air compressor, so we can,uh, the air compressor can be operated off-load for a few minutes until the engine warms up.

We have tanks,uh, rated at 4,900 PSI. We have two of those, we have another tank with working pressure of 1,600 PSI. and ,uh, we, like I say, utilizing the the low pressure tank and the high pressure tank, we can demonstrate a seven minute air up.

Or, if we just pop it out of both high pressure tanks, but what we would prefer to do is to demonstrate the fast fill for you out of two tanks and then while we're doing other things, we want to run the air compressor for you, and let you take your,uh, energy readings.

There's one other energy reading we can take, I was experimenting with it yesterday, because you said you wanted us to be ready to make a presentation, the uh, if you look on your wristwatch and you count the foot gauge on the meter, and, and you put your finger on the second hand here and then you count to see how many times the foot gauge turns around and multiply by 60 you get a pretty accurate reading of how much gas you're using.

But,uh, with a little time left, I've got a little blanket, we can sit right down there by the gas meter and we can time it and we can actually count the RPM's and run the compressor say for 20 minutes or 30 minutes while it's recompressing this tank and you can get an accurate reading of how much gas this system is using.

Uh, another thing we have on the ,uh, air station,uh, the hose to hook up to the car we have provisions where when we want to disconnect or to connect it we have a method of bleeding off the pressure so that we can disconnect from this and the car has one of these on it to fill and the other two teaching vehicles that we demonstrate the sequential re-use , the power boosting,uh, factor of sequential re-use, well,uh, we just have three scuba tanks in the back of each one of those, because we want to drive so far on one tank and then we'll do that for you and we'll show you and demonstrate it to you.

Okay, uh, the scale up of a compressor, uh, did we get the information from Ingersoll yet?

Toby Butterfield: "It did not arrive yet."

Terry Miller: " We'll forward some to you."

Toby Butterfield: "Jack Culp was going to send the scale up information on a compressor with a 100 horse electric motor and compare it to a 15 horse electric motor so that we could get the kilowatt consumption."

Terry Miller: "Right, you see we buy our natural gas here at retail and we're tickled to death with the economy of it, we're tickled to death with the fact that we're gonna be able to scrub our exhaust and come up with a total transportation system.

The whole total transportation system will be practically zero emission. Alright, that that warrants doing a little checking into, okay?

Uh, we're gonna also,uh, I lost my train of thought there for just a minute, we,uh,

Toby Butterfield: "The cost."

Terry Miller: "Yeah the cost for scaling up, that's right cause we haven't discussed this much any more.

I remembered that he and Bob Kletzli both talked to us pressure products, and Ingersoll-Rand they tell us that ,oh, let's get back to wholesale-retail if we can take you south to Shoal Creek and we can show you a jet engine down there ,uh, manufactured by Sun, uh, Sun something ,uh, it's a jet engine that operates on natural gas, and a jet engine drives a compressor.

They put their gas down the pipeline at 900 PSI. Now we're getting the wholesale-retail bit of the whole thing.

We have two jet engines setting right out in Joplin on on Shoal Creek at Riverton on the way home and there,uh, uh, jet engines that are sitting there running on natural gas that they buy off of Williams' pipeline and they generate electricity with this natural gas and they pay, Empire District Electric Company has a building over there that we call that Taj Mahal, it is an elaborate structure. It is a laughable with a boardroom that occupies half of a floor and they use natural gas to generate electricity and they run it through the power lines and use a lot of it, they run through transformers and use, lose a lot of it, they sell it to us at a price we want to pay they're able to afford to pay for all their employees and all their medical insurance and their hospitalization and their pension fund and splitting stock and all this burning natural gas to generate electricity to run through the power lines to pay their linemen and thay can afford to do all this with natural gas.

Now, if you're figuring on energy and, and, and commerce and all, we can sure as the devil burn that natural gas one time and scrub the exhaust and drive on the Kinetic energy that we used to compress with it without being penalized by Ohm's Law in any way.

And, if we're not energy efficient, I don't know who is.

It's the same way,uh, with the electricity, anywhere they generate electricity with, with all the energy burns and chemical conversions and they bring you electricity in town and people think it's a miracle, they plug their battery car in and they think it's a miracle.

Well, it's not, they still have the total concept, the whole transportation technology does pollute, you see, it does pollute, the whole transportation technology pollutes.

Alright, we have a technology which we believe can be cleaned to be absolutely non-polluting."

Toby Butterfield: "The scaling-up."

Terry Miller: "Uh, okay, scaling up. Well, I wanted to explain that wholesale-retail on the gas engine what we envision and Ingersoll-Rand says it's possible, it'll work is to have a natural gas engine located out of town by a pipeline will other people be interested in selling air? Sure well they can compress air with a big turbine and a big scaled-up air compressor and bring the compressed air into town via a line just like cable TV into other tanks in different parts of the city and have air-up stations.

In lieu of that for now,uh, a 15T-5 air compressor and a couple tanks works fine, we've got two more air compressors and Pressure Products says they'll give some more tanks as soon as we get the other compressor running.

Alright, scaling up. If you scale up your compressor, we know that there's a definite savings in energy use to scale up, it's the bigger your compressor, the cheaper your air and we don't have figures on it, but I've always I've known this for several years, I don't worry about because what we have now is economically feasible, by the time you get your reading on how far you can go with the car, and you equate that with the fact we need, we need a transmission that will shift for us, uh, we need engineering help, but our technology is sound and it's, and it's definitely energy efficient. It definitely is energy efficient.

And our air station is,uh, we just about,well we've covered our air station and scale up and all that perhaps right now you could write, you could let us know ,uh, and write down and consult with us briefly on things you want to see. Or I can just lead off to tell you what we can show you and then we'll go do it."

Ralph Fleming: " Well,uh, one of the questions I had was ,uh, so we can determine how much gas the engine uses to compress this air."

Terry Miller: "You bet."

Ralph Fleming: "But do we know how much air is being compressed?"

Terry Miller: "You bet."

Ralph Fleming: "In cubic feet per minute?"

Terry Miller: "21 cubic feet per minute."

Toby Butterfield: "It's 21.5 CFM, I believe that's correct, yes."

Terry Miller: "My Uncle Raymond always told me, you go with what works and we want you to make your energy readings but by the same time, we want to be able to fill the car and see how much time it takes to fill the tanks back up to where they were and give you your readings that you want too.

There's one other reading that I want you to have the air, the air compressor can be run at 600 RPM which means that we can slow the V-8 engine to a thousand.

Now we'd like for you to take a gas reading at a thousand because at at a thousand RPM, we need a bigger pulley on the engine so we can slow it down, the engine will slow down to 900 RPM and still pull the compressor.

But we only slow it down to a thousand because Ingersoll-Rand tells us for lubrication, we need to keep the compressor above 600 RPM. So if we can, we want to drop the the engine, the V-8 engine down still driving the compressor while the tank is being topped out at four thousand lbs pressure and let you take a gas reading then and I think you'll find that you're getting down to to around 160 cubic foot per minute, but it'd be an interesting reading to have, but we don't stand by that reading, it's just the fact that we can demonstrate that that when you run the engine slower, you see it's a honker engine and it's capable of putting out more."

Ralph Fleming: " Well, uh, when we , you gonna fill this car up to the brim?"

Terry Miller: "We'll fill it up to whatever you want, but..."

Ralph Fleming: " Well whatever pressure you drive it for and you're going to drive it around until it quits?"

Terry Miller: "Well you can, you can, you can drive it, we'll go with you, you can drive it just see how many, how long you can drive and where you can go. We're not, we haven't even thought about that, the reason we haven't about speed is real simple, and I can tell you why.

Uh, we haven't thought about while the car is can attain a speed of 30 MPH after about three blocks because it's in high gear, but ,uh, it was actually designed and we won't apologize for this, this is an engineering fact.

When I put the engine together, when we built the car, we knew that it was geared for 23.5 miles an hour and if we're driving along at an and I'll be able to tell you now if you hear the exhaust, it sounds just about right it's not too loud and we're just clipping along easy and if you'll count the exhaust strokes, you'll be able to tell how fast the engine's turning and when the engine's turning 40 RPM, we're going 23.5 MPH.

Uh, granted this is the only, this is ONE! engineering thing that we can do, the car is geared, now we can go faster, uh, we can go up to 35, 37, 36, MPH, uh, all we need is a slight,uh, you know not an incline, but we're in high gear, a slight decline,uh, we can go to North Main, drop in at 20th Street and drive to 10th and we can be up 30,36, 37 MPH, no problem, it's just a very slight decline, but we're in high gear.

The limiting factor, and you'll be able to tell, is the exhaust will be so loud we, we are well past our point of non-productivity and we're eating up air.

We're eating up air because we've reached the point that which this cylinder simply will not vent and port this much air any further.

But we feel and we'd like to have **engineering help** to show that if we had a transmission that starts out at 1 to 4 and can shift to 1 to 10 and then on up to 1 to 12 and maybe on up to 1 to 15 that we'll have an engine that's in the optimum range all the way up."

Ralph Fleming: "Yeah, I understand"

Terry Miller: "I do know one thing, Mr. Fleming, you've never had anybody to approach you with this type of technology before. I mean it's a little different you know,uh, but it does make sense, and it does work."

Terri Robbins: "Is Mr. Fleming wanting to know I think like if we took the car out say on one or two tanks or air, how far would it go before it just quits? What's the capacity? And I'm sure and you're not sure(garble?)"

Ralph Fleming: "The thing about it is, what I'm trying to get a handle on is how much, how much it takes to to propel a car. We can, we know pretty well how much energy it takes to drive a car."

Terry Miller: "uh huh"

Ralph Fleming: "You know, regardless of what kind of engine you've got."

Terry Miller: 'Yeah."

Ralph Fleming: " And its' approximate speed and the acceleration and all that."

Terry Miller: "Uh huh."

Ralph Fleming: "But what I'm tryin to get a handle on is that if , let's say you're goona run at 23 1/2 miles per hour, I want to know how far the car will go and with those tanks charged with 3000 till we get down to 500."

Terry Miller: " Can you help us figure that out? I'll be the first to admit to you that I'm not an engineer, Toby Butterfied is a jeweler, I'm an aircraft mechanic, I have a license to teach meteorology and civil air regulations and Link trainers and all that kind of stuff.

I am familiar with air. I haven't found any place in town where I can drive 30 MPH. I haven't found any place in town where I can consistently drive at 23 but my average driving speed in the car varies any where from 4MPH to 30 MPH depending on what I can do.

We,uh, we have never put the car on a racetrack because we think that is silly to drive a car on a racetrack when we built it to drive in town.

We do know and Ken Turley, our test driver, can tell you that he has driven the car for 2 1/2 hours. But that is just putting around. Now ,uh, we can demonstrate."

Ralph Fleming: "Now, uh, was that without a recharge?"

Terry Miller: " Oh, that's right, yeah, don't we wish that you could stay another day , we could ring that car out."

Ralph Fleming: " Well, I mean, I mean 2 1/2 hours you still got to specify what the ,uh, speed of it was and how far it went."

Toby Butterfield: "It's probably an average."

Terry Miller: "I don't have to, let me tell you why I don't have to, I don't have to because that's for guys like you and that's for the Energy Dept. and that's for the rocket scientists that Clinton says will check into this.

You see, all we know is, it works, and we know that the average is, did you figure up the average cost of driving the car for an hour, putting around town, what was it, Toby?"

Toby Butterfield: "35 cents per hour."

Terry Miller: "For the gas."

Terri Robbins: "That's city driving."

Toby Butterfield: "That's stop and go, stop and go driving."

Terri Robbins: "You would have to take it to a track, start it, maintain it at a constant speed and go for it. That has not been done, those , those standardized tests have not been done."

Ralph Fleming: "Well,uh, I'm not you know, I'm not trying to be negative or anything but when you sell a product to a customer."

Terry Miller: " We're not trying to sell a product to a customer."

Ralph Fleming: "No, I know, but if the technology ever makes it in the marketplace, somebody's gonna be selling it."

John Robbins: "Right."

Terri Robbins: "Definitely."

Terry Miller: "Right."

Ralph Fleming: " So what I'm saying is that and I'm not you know, I'm not, this has nothing to do with my evaluation or my reporting to them, but."

Terry Miller: "Right, I understand."

Ralph Fleming: " You've got to consider what the customer wants, you know, you might be willing to drive your car around town in Joplin, for example, uh, with a top speed of 30 MPH, but somebody in L. A. that's used to freeway driving, he's not gonna be satisfied with that. So, that's the real world to it."

Terry Miller: " Alright, let me answer you question, I'm sorry I didn't know we had this, let me answer the question. You, you want to know who'll buy something?"

Ralph Fleming: " Well, I think, I think the Energy Dept. when they consider commercial viability or is it, you know, something that the consumer's going to buy ?"

Terry Miller: "I think so absolutely, let me tell you why. We believe that they'll buy the car because they can drive it all day. There is no, they're spending 43 billion this year, no 43 million dollars this year, they're spending ,uh, for ,uh, battery car research.

And even Chrysler says they won't have anything 'til '98 and that that will they'll be terribly expensive, take time to charge and requires and requires more time for charging all the way through."

Ralph Fleming: "Oh, I understand that, I'm not, I mean personally I don't and the jury's still out on electric cars."

Terry Miller: " Right."

Ralph Fleming: " Uh, this is all, you want to hand this to me?"

Terry Miller: " That's yours."

Ralph Fleming: " Okay."

Terry Miller: "The Jury we don't..."

Ralph Fleming: " You see, you see, the thing about it is and and again I'm ~~not~~ just talking, nothing to do with my evaluation."

Terry Miller: " Right."

Ralph Fleming: " But,uh, the reason that the auto companies are looking at electric cars is that, uh, California's put this mandate that 2% of their sales will be zero emission vehicles."

Terry Miller: " Uh, huh."

Ralph Fleming: " But that still doesn't mean the customers are gonna buy 'em when they get into the marketplace."

Terri Robbins: "Right."

Terry Miller: " From what I've heard, and from what I've heard from our men in California, they won't because you can't make me buy a battery car that I can't have access to all day long, you can't do it. uh"

Terri Robbins: " And at the market~~place~~able prices, they're going to be outrageous to the consumers."

Terry Miller: "Right, Right now"

Toby Butterfield: " Can I just say something?"

Terry Miller: " Go ahead."

Toby Butterfield: " You know, I found the response that people in our area have had in driving the car, and riding in the car, is,uh, is extremely,uh, jubilant,uh, amazement and,uh, acceptance and interest in the idea of such a car.

Uh, people get excited about it, they enjoy the idea,uh, they enjoy the ride, women seem to just think it's a delightful car, they think it's really a"

Terri Robbins: "It isn't frightening technologically."

Toby Butterfield: "And, and,and, and, and if they're, if they're so willing to accept in its sort of limited and primitive condition with a fixed gear ratio of 7 to 1 and certainly not as many air cylinders in in the car to store air as we could put in there, if we had them which would only increase that range of 2 1/2 hours of commuting to more,uh, in a town this size not too many people drive 2 1/2 hours to work."

Terry Miller: " Here's where we stand. Uh, battery cars we figure are obsolete compared to our technology because we have something that will work now. Uh, this is our opinion. Compressed Air-powered car technology demonstrated by us, uh, is now recognized by the U.S. Dept. of Energy as an alternative fuel vehicle. that we do have. They said that since we don't burn gasoline or diesel, we're an alternative fuel vehicle.

Uh, we're rated zero emission by the United States Environmental Protection Agency, EPA, we have met the requirements for certification by California Air Resources Board for mandated zero emission vehicles, uh, we qualified for federal income tax credit, 10% of total vehicle purchase price as a Z.E.V.

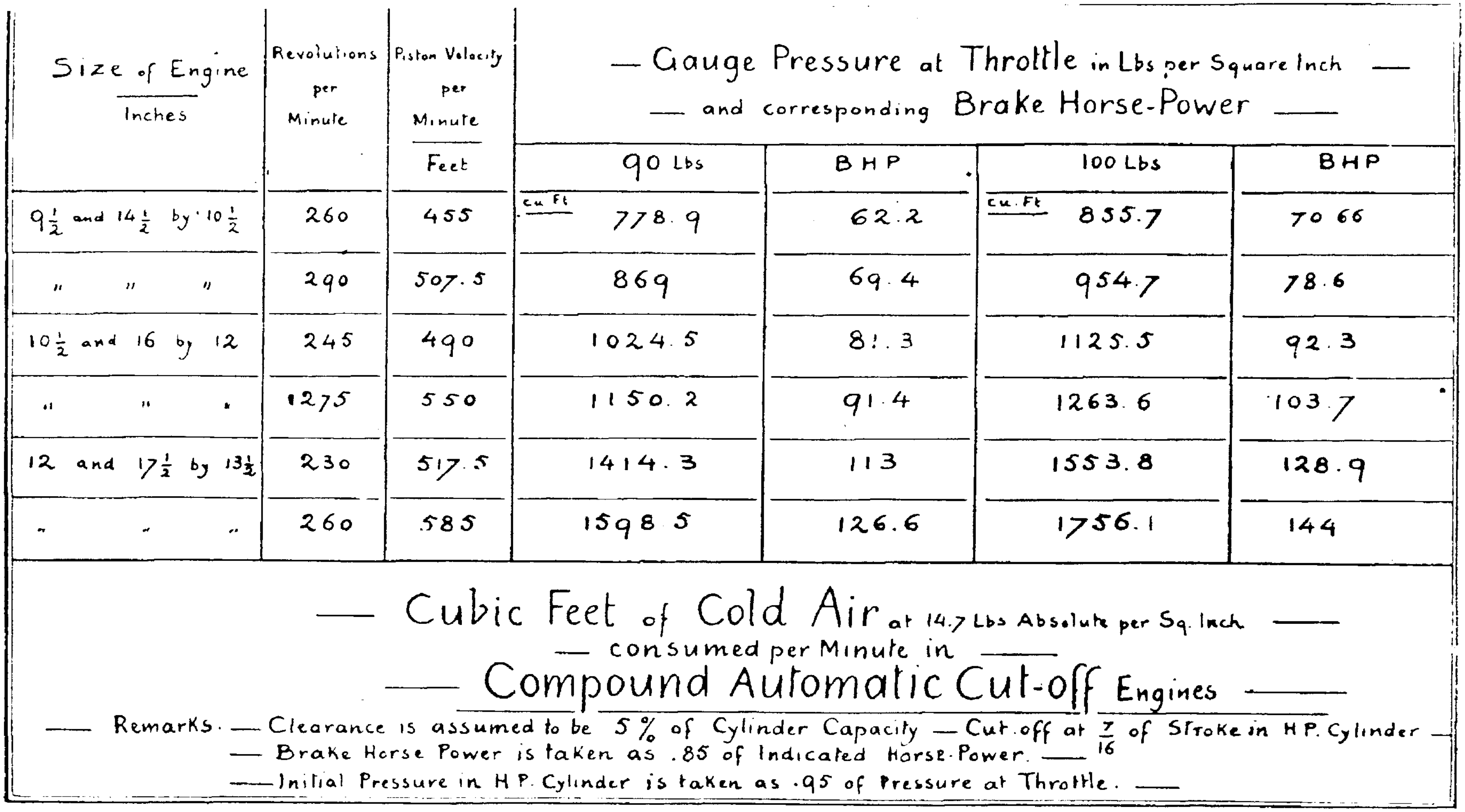
Uh, we qualified for the California state sales tax exemption. Uh, we have authority gained by public demonstration of our Chevrolet's 5 minutes,uh, no heat recharge capability.

There's a lot of things we have that are selling points.

Let's go play with the cars."

Ralph Fleming: "Okay,uh."

Note: At this time, the participants in the meeting adjourned to the National Muffler Shop at 920 East Seventh St. in Joplin, Missouri for a demonstration of the technology employed in the air-powered car through an examination of the demonstration cars and the apparatus used for compressing the air used in the demonstration cars by Mr. Fleming and some driving in actual traffic conditions with Terry Miller acting as driver and Mr. Fleming as passenger.



Size of Engine Inches	Revolutions per Minute	Piston Velocity per Minute	— Gauge Pressure at Throttle in Lbs per Square Inch — — and corresponding Brake Horse-Power —			
		Feet	90 Lbs	BHP	100 Lbs	BHP
9½ and 14½ by 10½	260	455	cu Ft 778.9	62.2	cu. Ft 855.7	70.66
" " "	290	507.5	869	69.4	954.7	78.6
10½ and 16 by 12	245	490	1024.5	81.3	1125.5	92.3
" " "	275	550	1150.2	91.4	1263.6	103.7
12 and 17½ by 13½	230	517.5	1414.3	113	1553.8	128.9
" " "	260	585	1598.5	126.6	1756.1	144

— Cubic Feet of Cold Air at 14.7 Lbs Absolute per Sq. Inch —
— consumed per Minute in —
— Compound Automatic Cut-off Engines —

— Remarks. — Clearance is assumed to be 5% of Cylinder Capacity — Cut-off at $\frac{7}{16}$ of Stroke in H.P. Cylinder —
— Brake Horse Power is taken as .85 of Indicated Horse-Power. —
— Initial Pressure in H.P. Cylinder is taken as .95 of Pressure at Throttle. —

FIG. 14.

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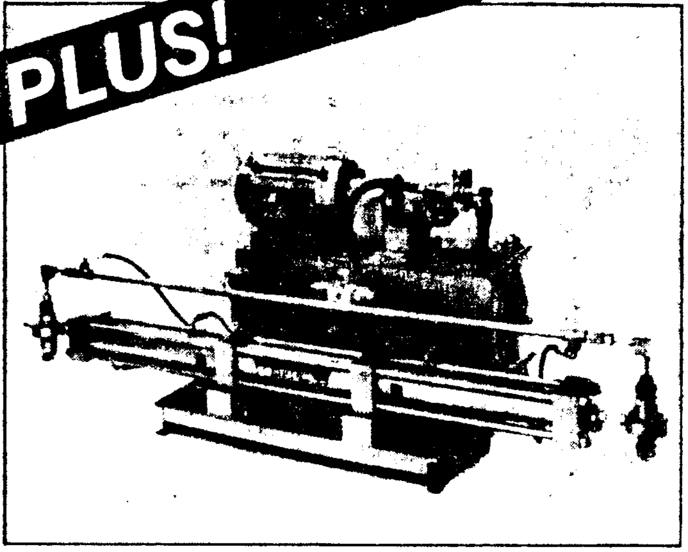

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The following performance data are from Terry Miller's book. They give the input and output pressures for each of the four pistons in his four stage compound engine, with seven different primary input pressures to the first cylinder.

	Cylinder One 2" bore	Cylinder Two 2½" bore	Cylinder Three 3¼" bore	Cylinder Four 4" bore
1. psig	100	45	20	4
2. psig	150	84	34	8
3. psig	200	104	46	17
4. psig	250	180	80	40
5. psig	300	190	100	51
6. psig	350	220	115	53
7. psig	400	232	126	64

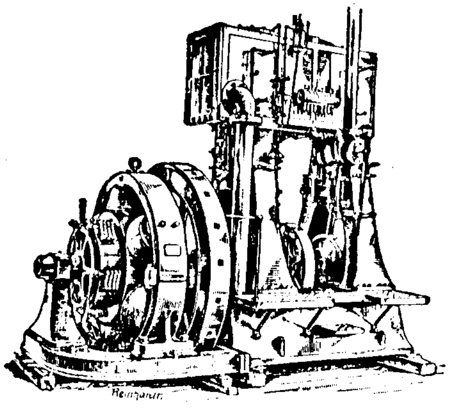

Fig. 264.

COMPOUNDING.

If steam is used at very high pressure in a single cylinder engine, and allowed to undergo the same stage of expansion as has been described under cut-off engines, the economy decreases rapidly after a certain number of expansions has been passed.

The steam entering the cylinder at high temperature will immediately give up some of its heat to the cylinder walls and head, thus heating them to a temperature almost equal to the entering steam.

As soon as cut-off has taken place, the pressure in the cylinder will fall as the piston advances ln the stroke, and correspondingly the temperature will fall below that of the cylinder walls, which now are compelled to give up their heat to the cooler steam, until exhaust takes place, when they will be cooled down to almost exhaust temperature during the exhaust stroke.

If the engine exhausts into the atmosphere without back pressure, the temperature of the exhaust would be 212 degrees, and if the boiler pressure is 120 pounds to the square inch, a temperature of nearly 350 degrees; the steam upon entering the cylinder will strike a surface 138 degrees cooler, and a considerable portion of it is condensed, which extra amount the boiler has to supply in order to fill the cylinder volume before cut off.

To expand steam from 120 pounds boiler pressure to atmospheric pressure, its volume will have to be increased nine times, that is, the engine would have to cut off at one-ninth of the stroke.

If now the cut-off be changed to one-third of the stroke, the steam would be only expanded three times, the pressure at exhaust opening being 40 pounds, and the corresponding temperature would be 275 degrees, a change of only 75 degrees, and consequently less cylinder condensation.

But at the end of the stroke the steam would be able to do a good deal of useful work, its pressure being 40 pounds above the atmosphere.

By allowing the steam to pass into another cylinder of such ample volume that its pressure need not be raised to fill the cut-off space, and then expanding it again three times, it will reach atmospheric pressure, and the change of temperature in this cylinder has been from 275 to 212 degrees — 63 degrees.

In the single engine a great portion of the heat which has been given up to the cylinder by the entering steam, is taken up again by the condensed steam during expansion, and the exhaust stroke, but still it is wasted through the exhaust pipe, while in the compound engine all the heat which is lost during admission, after being taken up again by the steam during expansion and exhaust, is used over again in the low pressure cylinder.

Thus it follows that in a compound engine the only loss by cylinder condensation is that taking place in the low pressure cylinder, which will be seen from the foregoing figures, is considerably less than one-half of that in the single engine.

Of course, there is some loss of heat in both types by outward radiation, which in either case is lost, but is reduced to a minimum in covering the cylinders with non-conducting material. If both engines would be run by a compressed gas, as air, for instance, so there would be no cylinder condensation, there would be no difference in the economy.

The amount of saving in favor of the compound over the single cylinder engine can safely be stated to be 20 per cent., but certainly varies with different engines, the only

---

Note.—The saving of fuel effected by compounding is illustrated by the remarkable statement that upon a trial trip of four hours, one of the first marine triple expansion engines ever made, developed a horse power with an expenditure of 1.28 of coal per hour.

comparison can be made between engines of the same type and condition. The triple expansion engine is again 20 per cent. more economical than the compound.

There are different systems of compounding. First, tandem compound, in which both cylinders are in line, and both their pistons arranged upon the same rod. The cylinders may be placed one before the other, as in a horizontal engine, or above each other, as in a vertical engine. The latter type is often called a steeple compound, and is frequently used in marine practice; these engines are often run without receiver.

Second, cross compound; in these engines both cylinders are operating separate cranks, which may be set at right angles to avoid dead centres and to distribute the load more evenly about the crank shaft; or the cranks may be set opposite to each other, as in the old Scotch non-receiver compound.

Most compound engines of the present designs are supplied with a receiver, which consists of an inclosed vessel of at least the same capacity as the high pressure cylinder, into which the high pressure cylinder exhausts; the steam passes from the receiver into the low pressure cylinder.

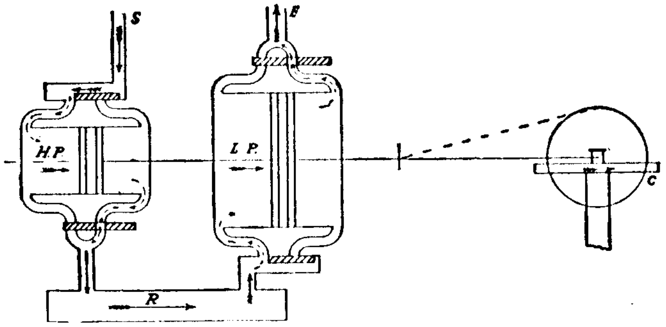

Fig. 265. DIAGRAM OF TANDEM COMPOUND ENGINE.

In a tandem compound engine the receiver is not such a necessity as in a cross compound with cranks at right angles, as both pistons start at the same time on their stroke, and thus the steam can pass directly over from the high pressure cylinder into the low pressure, while in a cross compound engine with cranks at right angles, the leading cylinder has completed one-half its stroke when the other begins, thus there has to be a receiver to take care of the high pressure exhaust until the low pressure cylinder begins its stroke, when the high pressure crank is leading, and if the low pressure cylinder is leading there has to be a volume of steam stored for it to begin its stroke with. If a tandem compound engine cuts off early in the stroke, a receiver will also be necessary in this type.

Fig. 265 represents a diagram of the arrangement of a tandem compound engine, while Fig. 266 is the same engine cross compounded.

The steam from the boiler enters at S, in the direction of the arrows, through the open steam port, into the high pressure cylinder marked H P, Figs. 265 and 266; the high pressure exhaust passes in the direction of the arrows into the receiver R, from whence it passes into the low pressure cylinder L P, from thence it is exhausted at E into the condenser.

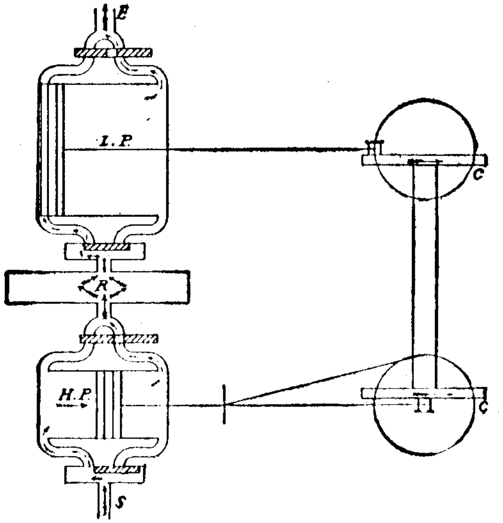

Fig. 266. DIAGRAM OF CROSS COMPOUND ENGINE.

The tandem compound has a single crank C, while the cross compound has two cranks, C C, set at right angles to each other.

It will be noticed that the high pressure crank, as shown in Fig. 266, is in its vertical position; the high pressure piston having completed more than one half stroke, while the low pressure piston is only at the commencement of the stroke.

NOTE.—The consumption of single cylinder non-condensing engines may be stated as 24 to 26 pounds of steam per horse power per hour, the same engines condensing, 19 to 21 pounds per horse power per hour. Compound non-condensing, 19 to 21 pounds per horse power per hour. Compound condensing engines, 14 to 16 pounds per horse power per hour. Triple expansion engines, 12 to 13½ pounds per horse power per hour. Quadruple expansion engines are advisable where very high steam pressures are employed, and where, for mechanical reasons, a four-cylinder machine is desirable. For all ordinary pressures the economy is about the same as triple expansion engines.

In general, it is desirable to make both cylinders of a compound engine contribute equal quantities of work.

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BY

W. C. POPPLEWELL, M.Sc.,

Assoc.M Inst.C.E.,

Senior Assistant Lecturer and Demonstrator in Civil and Mechanical Engineering at the Yorkshire College, Leeds; formerly Assistant to the Professor of Engineering in the University of Edinburgh; Heywood Exhibitioner and Trevithick Scholar at the Owens College, Victoria University.

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CHAPTER XXIX.

Compound Expansion and Compound Engines.

In the engines we have so far discussed it has been assumed that the steam does the whole of its work in one cylinder. But in most modern engines of any size, with the exception of the majority of locomotives and some small stationary engines, what is known as *compound expansion* is employed. Engines in which this is used are called compound engines. The reasons for their existence are several.

It will be remembered that, arguing from purely theoretical considerations, we found at an earlier part of these notes the efficiency of a steam engine to increase as the pressure of the steam employed was increased. Besides this improvement in thermal economy, it is obvious that an engine working at a high pressure will not require to be as large as an engine developing the same power, but working at a lower pressure. In the evolution of the steam engine from its earlier forms, the efficiency has been improved step by step, and slow and almost imperceptible increases of boiler pressure have been among the most potent factors which have helped to bring about this increased efficiency. But there is a limit to the use of high-pressure steam in one cylinder, because, if the final pressure is to be always the same, which is approximately the case, it is clear that for higher initial pressures, with the same final pressures, the ratios of expansion used must be greater. Now, it is found that the fact of cylinder condensation taking place imposes a limit beyond which it is not economical to expand the steam. This is chiefly due to the fact that a large ratio of expansion means a large range in the cylinder temperatures between initial and exhaust temperatures, and we know, from what has already been said, that a large range of temperature means increased initial condensation. In practice it is found that profitable expansion cannot be carried far beyond a ratio of 4 to 1 or 5 to 1. This is also shown to be so from experimental results on Table III. (page 331), where the steam consumptions are given for an engine working with various ratios of expansion; here the most economical ratio was found to be 5·6 – 1. So, in order to get over this cause of loss with high pressures, it has become customary to divide the expansion into stages taking place in different cylinders, so that the actual range of expansion in each cylinder is comparatively small.

A second reason why it is better to expand in stages when using high pressures is that by so doing the work lost in the re-evaporation of the initially condensed steam can be recovered either in part or wholly. It will be remembered that the steam condensed in the early part of the stroke is re-evaporated either during the latter part of the working stroke, during the exhaust stroke, or partly in one and partly in the other. Any re-evaporation which takes place during the exhaust stroke is detrimental to the economy of the engine, because the re-evaporated steam does work, not upon the piston in the form of useful work, but as negative work acting against the piston. In single-cylinder engines the steam thus re-evaporated, after doing work against the piston, is allowed to make its way into the atmosphere in a non-condensing engine, or into the conddenser in the case of a condensing engine.

But if the engine is a compound one, this exhaust from the high-pressure cylinder, containing the re-evaporated steam, is allowed to pass into the steam chest of the second or low-pressure cylinder, and thence into the cylinder itself, where it does work upon the low-pressure piston; and in this way work which would otherwise have been lost is recovered, and put to a useful purpose.

In addition to the increase of actual initial condensation, due to a large range of temperature in the cylinder, a large ratio of expansion also means a corresponding increase of the liquefaction of the expanding steam, due to the performance of work by the steam; and this aggravates the evils of re-evaporation during exhaust, and consequently affords another reason in favour of stage expansion.

The third reason in favour of compound expansion is to be found in the fact that the stresses upon the engine parts are more nearly equalised, and, moreover, there is a more uniform turning effort on the crank shaft. Thus, supposing that the initial pressure of the steam on the piston is 150 lb. per square inch absolute, and the final pressure 10 lb. per square inch absolute, the pressure communicated to the piston rod at the beginning of the stroke will be fifteen times as much as that at the end, a difference which will both add to the first cost of the engine and will be exceedingly awkward to deal with in its working. If, however, compound expansion is employed, the final pressure in the high-pressure cylinder will probably be about 60 lb. or 70 lb. per square inch, and the ratio of initial to final pressure reduced to about one quarter of what it was previously. In this second case, also, the work will be more equally distributed, part being on one crank and part on the other.

Compound expansion has been referred to so far as being spread over two cylinders, but at the present day, when pressures have become so high, expansion is often carried out in three stages or sometimes four. In the former of these cases we have what are known as "triple-expansion" engines, and in the latter "quadruple-expansion" engines.

In designing compound, triple, or quadruple expansion engines, a very important preliminary step is that of determining the cylinder ratios—that is to say, the relative sizes of the respective cylinders. Let us take an example of this. The boiler pressure of the steam is to be, say, 150 lb. per square inch. Allowing a fall of pressure between the boiler and the engine of 5 lb., this becomes 145 lb. above the atmosphere, or 160 lb. absolute. Then, assuming the back pressure in the condenser to be 5 lb. absolute, and the terminal pressure 10 lb., there is a difference between the initial and final pressures of 160 lb. − 10 lb. = 150 lb. per square inch, or a total ratio of $\frac{160}{10} = \frac{16}{1}$. Suppose the engine to be of the triple-expansion type. In apportioning the difference of pressure in each cylinder, the endeavour should be to make the ranges of temperatures somewhere about equal. The temperature of steam at 160 lb. absolute is 363 deg., and that corresponding to 10 lb. pressure is 193 deg., so that the range of temperature will, in that case, be 363 − 193 = 170 deg. If we divide this by 3, the drop of temperature per cylinder will be $\frac{170}{3} = 57$ deg. (roughly).

The initial temperatures in the three cylinders respectively will then be—

High-pressure		363 deg.
Intermediate..................	363 − 57 = 306	„
Low-pressure..................	306 − 57 = 249	„

These temperatures correspond to the following absolute pressures :—

Temperature.	Pressure.	
363	160	pounds per square inch.
306	74	„ „ „
249	30	„ „ „

These should be approximately the initial pressures in the respective cylinders, and also, assuming that there is no drop of pressure between the exhaust of one cylinder and the steam chest of the one following, 74 lb., 30lb., and 10 lb. per square inch will be the final pressures in these cylinders.

So, neglecting clearance, the ratios of expansion in the successive cylinders will be—

$$\frac{160}{74} = \frac{2{\cdot}16}{1}$$

$$\frac{74}{30} = \frac{2{\cdot}46}{1}$$

$$\frac{30}{10} = \frac{3}{1}.$$

Now, working from these results, in order to arrive at the ratio of the cylinder's diameter, we will first assume, as is generally the case, that the strokes of all three engines are alike ; then the volumes of these cylinders will be proportional to the areas. Suppose, for the sake of simplicity, that 1 lb. of steam is used per stroke. At the end of the stroke of the first cylinder the steam will be at a pressure of 74 lb. per square inch, and 1 lb. of steam at this pressure occupies 5·79 cubic feet ; this will be the volume of the cylinder.

Similarly, the intermediate cylinder occupies a volume corresponding to the volume of 1 lb. of steam at 30 lb., which is 13·46 ; and the low-pressure cylinder, similarly, has a volume of 37·87 cubic feet.

Therefore the ratios of the cylinder areas, which are the same as the ratios of the cylinder volumes, are as follow :—

High-pressure.....................	5·79, or 1.
Intermediate-pressure	13·46, or 2·33.
Low-pressure	37·87, or 6·56.

And the cylinder diameters being as the square roots of the areas, their ratios are—

$$\sqrt{1} = 1{\cdot}00.$$

$$\sqrt{2{\cdot}32} = 1{\cdot}55.$$

$$\sqrt{6{\cdot}56} = 2{\cdot}56.$$

The above investigation is of necessity only approximate, and is simply intended to indicate the lines which are to be followed in arriving at the proper ratios of cylinder diameters. In this we have not taken into account the many practical facts which have to be allowed for. The main idea is to so adjust the ratios that the range of temperature shall be as nearly as possible the same in each cylinder. If the pressure is low to begin with, so that two expansions can be used, a two-cylinder or compound engine is employed. If the boiler pressure is 200 lb. per square inch, or upwards, it is advisable to use a quadruple-expansion engine. Mr. Dunlop, in *The Practical Engineer* Pocket-book, gives the following simple rules for getting the cylinder ratios of compound, triple-expansion, and quadruple-expanson engines :—

Let E = the total number of expansions of the steam ;
A = the area of the low-pressure cylinder ;
a = the area of the high-pressure cylinder ;
a_2 = the area of the intermediate cylinder in triple engines ;
a_3 = 1st intermediate cylinder of quadruple engine ;
a_4 = 2nd intermediate cylinder of quadruple engine ;

Then,
$$a = \frac{A}{\sqrt{E}}$$

where E is 11 or under (that is, when the engine is compound);

$$= \frac{a_2}{\sqrt[3]{E}}$$

where E is 19 or over 11 (that is, where the engine is triple-expansion);

$$= \frac{a_3}{\sqrt[4]{E}}$$

where E is 40 or over 19 (that is, where the engine is quadruple expansion). Also,

$$a_2 = \frac{A}{\sqrt[3]{E}}$$

$$a_3 = \frac{a_4}{\sqrt[4]{E}}$$

$$a_4 = \frac{A}{\sqrt[4]{E}}$$

Now let us see how these rules compare in their results with these we have found in the given examples.

Here E = 16 ; and the ratios of the cylinder areas will be, according to Mr. Dunlop's rules—

$$\begin{array}{lccccc} & a & : & a_2 & : & A \\ \text{or,} & a & : & \sqrt[3]{E}\,.\,a & : & \sqrt[3]{(E)^2}\,.\,a \\ \text{or,} & 1 & : & \sqrt[3]{E} & : & \sqrt[3]{(E)^2} \end{array}$$

or, putting E = 16, the actual values of these ratios become

$$1 \quad : \quad 2{\cdot}52 \quad : \quad 6{\cdot}35.$$

And the ratios of the diameters will be as the square roots of these numbers, or,

$$1 \quad : \quad 1{\cdot}59 \quad : \quad 2{\cdot}52.$$

The results previously found were :—

$$1 \quad : \quad 1{\cdot}55 \quad : \quad 2{\cdot}56,$$

which shows a fair agreement between the two methods.

In fig. 65 is given a graphic representation of the expansion in the triple-expansion engine referred to above. With the usual notation, A B and A C are respectively the lines

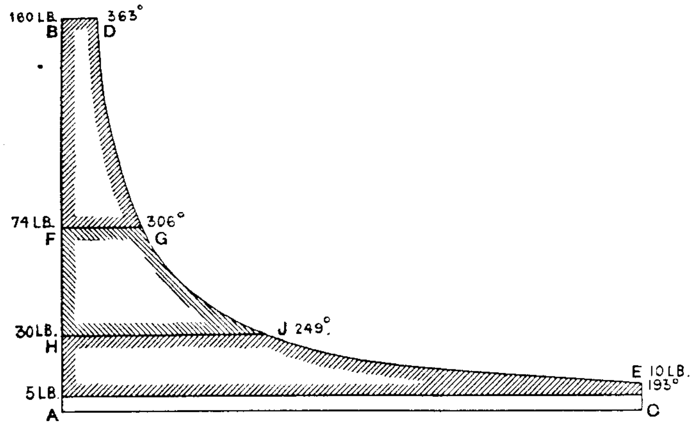


FIG. 65.

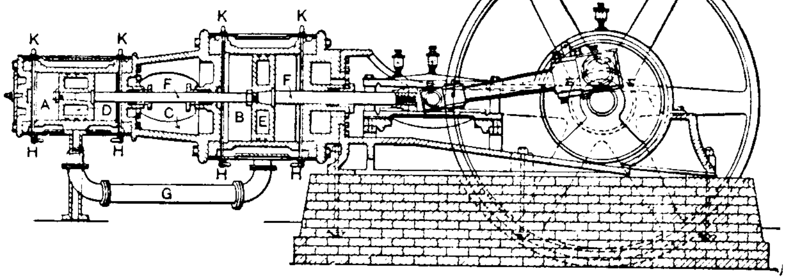
of zero volume and zero pressure. A B is the initial pressure of the steam as it enters the cylinder, and B D is its initial volume; similarly E C and A C are the final conditions. If the expansion all takes place in one cylinder, the ratio of expansion will then be

$$\frac{A\,C}{B\,D}$$

But expansion takes place in three stages, as already described, and the initial and final conditions in the three stages are as follow :—

Cylinder.	Initial pressure	Initial volume.	Final pressure.	Final volume.	Ratio of expansion (approx.)
1	A B=160 lb.	B D=2·8 c. ft	A F = 74 lb.	F G=5·8 c. ft	$\frac{2\cdot16}{1}$
2	A F= 74 ,,	F G=5·8 ,,	A H = 30 ,,	H J=13·5 ,,	$\frac{2\cdot4}{1}$
3	A H= 30 ,,	H J=13·5 ,,	C E = 10 ,,	A C=37·9 ,,	$\frac{3}{1}$

COMPOUND ENGINES



COMPOUND ENGINES.

Compound, Triple- and Quadruple-expansion Engines. —A compound engine is one having two or more cylinders, and in which the steam after doing work in the first or high-pressure cylinder completes its expansion in the other cylinder or cylinders.

The term "compound" is commonly restricted, however, to engines in which the expansion takes place in two stages only—high and low pressure, the terms triple-expansion and quadruple-expansion engines being used when the expansion takes place respectively in three and four stages. The number of cylinders may be greater than the number of stages of expansion, for constructive reasons; thus in the compound or two-stage expansion engine the low-pressure stage may be effected in two cylinders so as to obtain the advantages of nearly equal sizes of cylinders and of three cranks at angles of 120°. In triple-expansion engines there are frequently two low-pressure cylinders, one of them being placed tandem with the high-pressure, and the other with the intermediate cylinder, as in mill engines with two cranks at 90°. In the triple-expansion engines of the steamers *Campania* and *Lucania*,

reprinted from
"Mechanical Engineer's Pocket-Book"
by William Kent 1903

with three cranks at 120°, there are five cylinders, two high, one intermediate, and two low, the high-pressure cylinders being tandem with the low.

Advantages of Compounding.—The advantages secured by dividing the expansion into two or more stages are twofold: 1. Reduction of wastes of steam by cylinder-condensation, clearance, and leakage; 2. Dividing the pressures on the cranks, shafts, etc., in large engines so as to avoid excessive pressures and consequent friction. The diminished loss by cylinder-condensation is effected by decreasing the range of temperature of the metal surfaces of the cylinders, or the difference of temperature of the steam at admission and exhaust. When high-pressure steam is admitted into a single-cylinder engine a large portion is condensed by the comparatively cold metal surfaces; at the end of the stroke and during the exhaust the water is re-evaporated, but the steam so formed escapes into the atmosphere or into the condenser, doing no work; while if it is taken into a second cylinder, as in a compound engine, it does work. The steam lost in the first cylinder by leakage and clearance also does work in the second cylinder. Also, if there is a second cylinder, the temperature of the steam exhausted from the first cylinder is higher than if there is only one cylinder, and the metal surfaces therefore are not cooled to the same degree. The difference in temperatures and in pressures corresponding to the work of steam of 150 lbs. gauge-pressure expanded 20 times, in one, two, and three cylinders, is shown in the following table, by W. H. Weightman, *Am. Mach.*, July 26, 1892:

	Single Cylinder.	Compound Cylinders.		Triple-expansion Cylinders.		
Diameter of cylinders, in..	60	33	61	28	46	61
Area ratios........	....	1	3.416	1	2.70	4.741
Expansions.....	20	5	4	2.714	2.714	2.714
Initial steam-pressures—absolute—pounds........	165	165	33	165	60.8	22.4
Mean pressures, pounds. .	32.96	86.11	19.68	121.44	44.75	16.49
Mean effective pressures, pounds..................	28.96	53.11	15.68	60.64	22.35	12.49
Steam temperatures into cylinders.......	366°	366°	259°.9	366°	293°.5	234°.1
Steam temperatures out of the cylinders....	184°.2	259°.9	184°.2	293°.5	234°.1	184°.2
Difference in temperatures	181.8	106.1	75.7	72.5	59.4	49.9
Horse-power developed...	800	399	403	269	268	264
Speed of piston...........	322	290	290	238	238	238
Total initial pressures on pistons, pounds..........	455,218	112,900	84,752	64,162	63,817	53,773

"Woolf" and Receiver Types of Compound Engines.—The compound steam-engine, consisting of two cylinders, is reducible to two forms, 1, in which the steam from the h.p. cylinder is exhausted direct into the l. p. cylinder, as in the Woolf engine; and 2, in which the steam from the h. p. cylinder is exhausted into an intermediate reservoir, whence the steam is supplied to, and expanded in, the l. p. cylinder, as in the "receiver-engine."

If the steam be cut off in the first cylinder before the end of the stroke, the total ratio of expansion is the product of the ratio of expansion in the first cylinder, into the ratio of the volume of the second to that of the first cylinder; that is, the product of the two ratios of expansion.

Thus, let the areas of the first and second cylinders be as 1 to 3½, the strokes being equal, and let the steam be cut off in the first at ½ stroke; then

Expansion in the 1st cylinder..	1 to 2
" " " 2d "	1 to 3½
Total or combined expansion, the product of the two ratios...	1 to 7

Woolf Engine, without Clearance—Ideal Diagrams.—The diagrams of pressure of an ideal Woolf engine are shown in Fig. 142, as they would be described by the indicator, according to the arrows. In these diagrams *pq* is the atmospheric line, *mn* the vacuum line, *cd* the admission line, *dg* the hyperbolic curve of expansion in the first cylinder, and *gh* the consecutive expansion-line of back pressure for the return-stroke of the first piston, and of positive pressure for the steam-stroke of the second piston. At the point *h*, at the end of the stroke of the second piston, the steam is exhausted into the condenser, and the pressure falls to the level of perfect vacuum, *mn*.

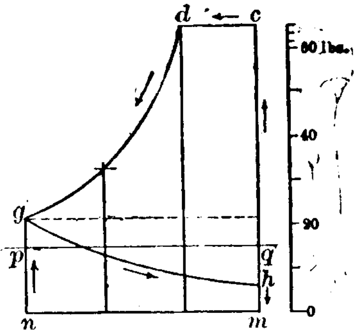


Fig. 142.—Woolf Engine—Ideal Indicator-diagrams.

The diagram of the second cylinder, below *gh*, is characterized by the absence of any specific period of admission; the whole of the steam-line *gh* being expansional, generated by the expansion of the initial body of steam contained in the first cylinder into the second. When the return-stroke is completed, the whole of the steam transferred from the first is shut into the second cylinder. The final pressure and volume of the steam in the second cylinder are the same as if the whole of the initial steam had been admitted at once into the second cylinder, and then expanded to the end of the stroke in the manner of a single-cylinder engine.

The net work of the steam is also the same, according to both distributions.

Receiver-engine, without Clearance—Ideal Diagrams.—In the ideal receiver-engine the pistons of the two cylinders are connected to cranks at right angles to each other on the same shaft. The receiver takes the steam exhausted from the first cylinder and supplies it to the second, in which the steam is cut off and then expanded to the end of the stroke. On the assumption that the initial pressure in the second cylinder is equal to the final pressure in the first, and of course equal to the pressure in the receiver, the volume cut off in the second cylinder must be equal to the volume of the first cylinder, for the second cylinder must admit as much steam at each stroke as is discharged from the first cylinder.

In Fig. 143 *cd* is the line of admission and *hg* the exhaust-line for the first cylinder; and *dg* is the expansion-curve and *pq* the atmospheric line. In the region below the exhaust-line of the first cylinder, between it and the line of perfect vacuum, *ol*, the diagram of the second cylinder is formed; *hi*, the second line of admission, coincides with the exhaust-line *hg* of the first cylinder, showing in the ideal diagram no intermediate fall of pressure, and *ik* is the expansion-curve. The arrows indicate the order in which the diagrams are formed.

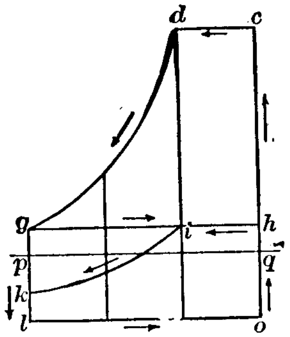


Fig. 143.—Receiver-engine, Ideal Indicator-diagrams.

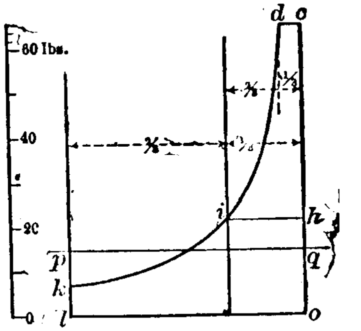


Fig. 144.—Receiver Engine, Ideal Diagrams reduced and combined.

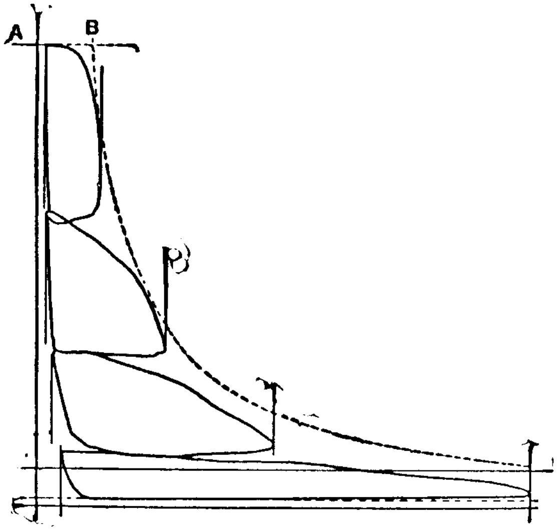
In the action of the receiver-engine, the expansive working of the steam, though clearly divided into two consecutive stages, is, as in the Woolf engine, essentially continuous from the point of cut-off in the first cylinder to the end of the stroke of the second cylinder, where it is delivered to the condenser; and the first and second diagrams may be placed together and combined to form a continuous diagram. For this purpose take the second diagram as the basis of the combined diagram, namely, *hiklo*, Fig. 144. The period of admission, *hi*, is one third of the stroke, and as the ratios of the cylinders are as 1 to 3, *hi* is also the proportional length of the first diagram as applied to the second. Produce *oh* upwards, and set off *oc* equal to the total height of the first diagram above the vacuum-line; and, upon the shortened base *hi*, and the height *hc*, complete the first diagram with the steam-line *cd*, and the expansion-line *di*.

It is shown by Clark (S. E., p. 432, *et seq.*) in a series of arithmetical calculations, that the receiver-engine is an elastic system of compound engine, in which considerable latitude is afforded for adapting the pressure in the receiver to the demands of the second cylinder, without considerably diminishing the effective work of the engine. In the Woolf engine, on the contrary, it is of much importance that the intermediate volume of space between the first and second cylinders, which is the cause of an intermediate fall of pressure, should be reduced to the lowest practicable amount.

Supposing that there is no loss of steam in passing through the engine, by cooling and condensation, it is obvious that whatever steam passes through the first cylinder must also find its way through the second cylinder. By varying, therefore, in the receiver-engine, the period of admission in the second cylinder, and thus also the volume of steam admitted for each stroke, the steam will be measured into it at a higher pressure and of a less bulk, or at a lower pressure and of a greater bulk; the pressure and density naturally adjusting themselves to the volume that the steam from the receiver is permitted to occupy in the second cylinder. With a sufficiently restricted admission, the pressure in the receiver may be maintained at the pressure of the steam as exhausted from the first cylinder. On the contrary, with a wider admission, the pressure in the receiver may fall or "drop" to three fourths or even one half of the pressure of the exhaust-steam from the first cylinder.

(For a more complete discussion of the action of steam in the Woolf and receiver engines, see Clark on the Steam-engine.)

Combined Diagrams of Compound Engines.—The only way of making a correct combined diagram from the indicator-diagrams of the several cylinders in a compound engine is to set off all the diagrams on the same horizontal scale of volumes, adding the clearances to the cylinder capacities proper. When this is attended to, the successive diagrams fall exactly into their right places relatively to one another, and would compare properly with any theoretical expansion-curve. (Prof. A. B. W. Kennedy, Proc. Inst. M. E., Oct. 1886.)



This method of combining diagrams is commonly adopted, but there are objections to its accuracy, since the whole quantity of steam consumed in the first cylinder at the end of the stroke is not carried forward to the second, but a part of it is retained in the first cylinder for compression. For a method of combining diagrams in which compression is taken account of, see discussions by Thomas Mudd and others, in Proc. Inst. M. E., Feb., 1887, p. 48. The usual method of combining diagrams is also criticised by Frank H. Ball as inaccurate and misleading (*Am. Mach.*, April 12, 1894; Trans. A. S. M. E., xiv. 1405, and xv. 403).

Figure 145 shows a combined diagram of a quadruple-expansion engine, drawn according to the usual method, that is, the diagrams are first reduced in length to relative scales that correspond with the relative piston-displacement of the three cylinders. Then the diagrams are placed at such distances from the clearance-line of the proposed combined diagram as to correctly represent the clearance in each cylinder.

Calculated Expansions and Pressures in Two-cylinder Compound Engines. (James Tribe, *Am. Mach.*, Sept. & Oct. 1891.)

TWO-CYLINDER COMPOUND NON-CONDENSING.

Back pressure ½ lb. above atmosphere.

Initial gauge-pressure		100	110	120	130	140	150	160	170	175
Initial absolute pressure		115	125	135	145	155	165	175	185	190
Total expansion		7.39	7.84	8.41	9	9.61	10.24	10.[illegible]9	11.56	11.9
Expansions in each cylinder		2.7	2.8	2.9	3	3.10	3.2	3.3	3.4	3.45
Hyp. log. plus 1		1.993	2.029	2.064	2.098	2.131	2.163	2.1[illegible]	2.223	2.238
Forward pressures	High	84.8	90.5	96	101.4	106.5	111.5	116.3	120.9	123.2
	Low	31.3	32.3	33.1	33.7	34.3	34.8	35.[illegible]	35.6	35.7
Back pressures	High	42.5	44.6	46.5	48.3	50	51.5	53	54.4	55
	Low	15.5	15.5	15.5	15.5	15.5	15.5	15.5	15.5	15.5
Mean effective pressures	High	42.3	45.9	49.5	53.1	56.5	60	63.[illegible]	66.5	68.2
	Low	15.8	16.8	17.6	18.2	18.8	19.3	19.7	20.1	20.2
Ratio cylinder areas		2.67	2.73	2.81	2.91	3	3.11	3.[illegible]	3.31	3.37

TWO-CYLINDER COMPOUND CONDENSING.

Back pressure, 6.5 lbs. above vacuum.

Initial gauge-pressures		90	100	110	120	130	140	150
Initial absolute pressures		105	115	125	135	1[illegible]	155	165
Probable per cent of loss		2.6	2.9	3.3	3.6	3.[illegible]	4.0	4.3
Total expansions		15.7	17	18.5	20	21.[illegible]	22.7	24.2
Exps. in each cylinder		3.96	4.13	4.3	4.47	4.6[illegible]	4.77	4.92
Hyp. log. plus 1		2.376	2.418	2.458	2.497	2.5[illegible]	2.562	2.593
Mean forward pressures	High	62.9	67.3	71.4	75.4	79.[illegible]	[illegible]3.2	87
	Low	15.25	15.55	15.9	16.2	16.5	16.75	17.05
Mean back pressures	High	26.5	27.8	29	30.2	31.[illegible]	32.4	33.5
	Low	4.3	4.3	4.3	4.3	4.3	4.3	4.3
Mean effective pressures	High	36.4	39.5	42.4	45.2	47.[illegible]	50.8	53.5
	Low	10.95	11.25	11.6	11.9	12.2	12.45	12.75
Terminal pressures	High	26.5	27.8	29.0	30.2	31.[illegible]	32.4	33.5
	Low	6.4	6.45	6.45	6.5	6.[illegible]	6.55	6.6
Initial pressure in l. p. cyl.		25.3	26.6	27.8	29	30.[illegible]	31.4	32.4
Ratio of cylinder areas		3.32	3.51	3.66	3.8	3.[illegible]	4.08	4.19

The probable percentage of loss, line 3, is thus explained: There is always a loss of heat due to condensation, and which increases with the pressure of steam. The exact percentage cannot be predetermined, as it depends largely upon the quality of the non-conducting covering used on the cylinder, receiver, and pipes, etc., but will probably be about as shown.

Proportions of Cylinders in Compound Engines.—Authorities differ as to the proportions by volume of the high and low pressure cylinders v and V. Thus Grashof gives $V \div v = 0.85\sqrt{r}$; Hrabak, $0.90\sqrt{r}$; Werner, $\sqrt{r}$; and Rankine, $\sqrt[3]{r^2}$, r being the ratio of expansion. Busley makes the ratio dependent on the boiler-pressure thus:

Lbs. per sq. in.	60	90	105	120
$V \div v$ =	3	4	4.5	5

(See Seaton's Manual, p. 95, etc., for analytical method; Sennett, p. 496, etc.; Clark's Steam-engine, p. 445, etc; Clark, Rules, Tables, Data, p. 849, etc.)

Mr. J. McFarlane Gray states that he finds the mean effective pressure in the compound engine reduced to the low-pressure cylinder to be approximately the square root of 6 times the boiler-pressure.

Approximate Horse-power of a Modern Compound Marine-engine. (Seaton.)—The following rule will give approximately the horse-power developed by a compound engine made in accordance with modern marine practice. Estimated H.P. $= \frac{D^2 \times \sqrt{p} \times R \times S}{8500}$.

D = diameter of l.p. cylinder; p = boiler-pressure by gauge;
R = revs. per min.; S = stroke of piston in feet.

Ratio of Cylinder Capacity in Compound Marine Engines. (Seaton.)—The low-pressure cylinder is the measure of the power of a compound engine, for so long as the initial steam-pressure and rate of expansion are the same, it signifies very little, so far as total power only is concerned, whether the ratio between the low and high-pressure cylinders is 3 or 4; but as the power developed should be nearly equally divided between the two cylinders, in order to get a good and steady working engine, there is a necessity for exercising a considerable amount of discretion in fixing on the ratio.

In choosing a particular ratio the objects are to divide the power evenly and to avoid as much as possible "drop" and high initial strain.

If increased economy is to be obtained by increased boiler-pressures, the rate of expansion should vary with the initial pressure, so that the pressure at which the steam enters the condenser should remain constant. In this case, with the ratio of cylinders constant, the cut-off in the high-pressure cylinder will vary inversely as the initial pressure.

Let R be the ratio of the cylinders; r, the rate of expansion; p_1 the initial pressure: then cut-off in high-pressure cylinder $= R \div r$; r varies with p_1, so that the terminal pressure p_n is constant, and consequently $r = p_1 \div p_n$; therefore, cut-off in high-pressure cylinder $= R \times p_n \div p_1$.

Ratios of Cylinders as Found in Marine Practice.—The rate of expansion may be taken at one tenth of the boiler-pressure (or about one twelfth the absolute pressure), to work economically at full speed. Therefore, when the diameter of the low-pressure cylinder does not exceed 100 inches, and the boiler-pressure 70 lbs., the ratio of the low-pressure to the high-pressure cylinder should be 3.5; for a boiler-pressure of 80 lbs., 3.75; for 90 lbs., 4.0; for 100 lbs., 4.5. If these proportions are adhered to, there will be no need of an expansion-valve to either cylinder. If, however, to avoid "drop," the ratio be reduced, an expansion-valve should be fitted to the high-pressure cylinder.

Where economy of steam is not of first importance, but rather a large power, the ratio of cylinder capacities may with advantage be decreased, so that with a boiler-pressure of 100 lbs. it may be 3.75 to 4.

In tandem engines there is no necessity to divide the work equally. The ratio is generally 4, but when the steam-pressure exceeds 90 lbs. absolute 4.5 is better, and for 100 lbs. 5.0.

When the power requires that the l. p. cylinder shall be more than 100 in. diameter, it should be divided in two cylinders. In this case the ratio of the combined capacity of the two l. p. cylinders to that of the h. p. may be 3.0 for 85 lbs. absolute, 3.4 for 95 lbs., 3.7 for 105 lbs., and 4.0 for 115 lbs.

Receiver Space in Compound Engines should be from 1 to 1.5 times the capacity of the high-pressure cylinder, when the cranks are at an angle of from 90° to 120°. When the cranks are at 180° or nearly this, the space may be very much reduced. In the case of triple-compound engines, with cranks at 120°, and the intermediate cylinder leading the high-pressure, a very small receiver will do. **The pressure in the receiver should never exceed half the boiler-pressure.** (Seaton.)

Formula for Calculating the Expansion and the Work of Steam in Compound Engines.

(Condensed from Clark on the "Steam-engine.")

a = area of the first cylinder in square inches;
a' = area of the second cylinder in square inches;
r = ratio of the capacity of the second cylinder to that of the first;
L = length of stroke in feet, supposed to be the same for both cylinders;
l = period of admission to the first cylinder in feet, excluding clearance;
c = clearance at each end of the cylinders, in parts of the stroke, in feet;
L' = length of the stroke plus the clearance, in feet;
l' = period of admission plus the clearance, in feet;
s = length of a given part of the stroke of the second cylinder, in feet;
P = total initial pressure in the first cylinder, in lbs. per square inch, supposed to be uniform during admission;
P'' = total pressure at the end of the given part of the stroke s;
p = average total pressure for the whole stroke;
R = nominal ratio of expansion in the first cylinder, or $L \div l$;
R' = actual ratio of expansion in the first cylinder, or $L' \div l'$;
R'' = actual combined ratio of expansion, in the first and second cylinders together;
n = ratio of the final pressure in the first cylinder to any intermediate fall of pressure between the first and second cylinders;
N = ratio of the volume of the intermediate space in the Woolf engine, reckoned up to, and including the clearance of, the second piston, to the capacity of the first cylinder plus its clearance. The value of N is correctly expressed by the actual ratio of the volumes as stated, on the assumption that the intermediate space is a vacuum when it receives the exhaust-steam from the first cylinder. In point of fact, there is a residuum of unexhausted steam in the intermediate space, at low pressure, and the value of N is thereby practically reduced below the ratio here stated. $N = \frac{n}{n-1} - 1$.
w = whole net work in one stroke, in foot-pounds.

Ratio of expansion in the second cylinder:

$$\text{In the Woolf engine, } \frac{\left(r\frac{L}{L'}\right) + N}{1+N};$$

$$\text{In the receiver-engine, } \frac{(n-1)r}{n}.$$

Total actual ratio of expansion = product of the ratios of the three consecutive expansions, in the first cylinder, in the intermediate space, and in the second cylinder,

$$\text{In the Woolf engine, } R'\left(r\frac{L}{L'} + N\right);$$

$$\text{In the receiver-engine, } r\frac{L'}{l'}, \text{ or } rR'.$$

Combined ratio of expansion behind the pistons $= \frac{n-1}{n}rR' = R''$.

Work done in the two cylinders for one stroke, with a given cut-off and a given combined actual ratio of expansion:

$$\text{Woolf engine, } w = aP[l'(1 + \text{hyp log } R'') - c];$$

$$\text{Receiver engine, } w = aP\left[l'(1 + \text{hyp log } R'') - c\left(1 + \frac{r-1}{R'}\right)\right],$$

when there is no intermediate fall of pressure.

When there is an intermediate fall, when the pressure falls to ¾, ⅔, ½ of the final pressure in the 1st cylinder, the reduction of work is 0.2%, 1.0%, 4.6% of that when there is no fall.

Total work in the two cylinders of a receiver-engine, for one stroke for any intermediate fall of pressure,

$$w = aP\left[l'\left(\frac{n+1}{n} + \text{hyp log } R''\right) - c\left(1 + \frac{(n-1)(r-1)}{nR'}\right)\right].$$

EXAMPLE.—Let $a = 1$ sq. in., $P = 63$ lbs., $l' = 2.42$ ft., $n = 4$, $R'' = 5.969$, $c = .42$ ft., $r = 3$, $R' = 2.658$;

$$w = 1 \times 63\left[2.42(5/4 \text{ hyp log } 5.969) - .42\left(1 + \frac{3 \times 2}{4 \times 2.658}\right)\right] = 421.55 \text{ ft.-lbs.}$$

Calculation of Diameters of Cylinders of a compound condensing engine of 2000 H.P. at a speed of 700 feet per minute, with 100 lbs. boiler-pressure.

100 lbs. gauge-pressure = 115 absolute, less drop of 5 lbs. between boiler and cylinder = 110 lbs. initial absolute pressure. Assuming terminal pressure in l. p. cylinder = 6 lbs., the total expansion of steam in both cylinders $= 110 \div 6 = 18.33$ lbs. Hyp log $18.33 = 2.909$. Back pressure in l. p. cylinder, 3 lbs. absolute.

The following formulæ are used in the calculation of each cylinder:

(1) Area of cylinder $= \frac{\text{H.P.} \times 33{,}000}{\text{M.E.P.} \times \text{piston-speed}}$.

(2) Mean effective pressure = mean total pressure − back pressure.

(3) Mean total pressure = terminal pressure × (1 + hyp log R).

(4) Absolute initial pressure = absolute terminal pressure × ratio of expansion.

First calculate the area of the low-pressure cylinder as if all the work were done in that cylinder.

From (3), mean total pressure = 6 × (1 + hyp log 18.33) = 23.454 lbs.

From (2), mean effective pressure = 23.454 − 3 = 20.454 lbs.

From (1), area of cylinder $= \frac{2000 \times 33{,}000}{20.454 \times 700} = 4610$ sq. ins. = 76.6 ins. diam.

If half the work, or 1000 H.P., is done in the l. p. cylinder the M.E.P. will be half that found above, or 10.227 lbs., and the mean total pressure 10.227 + 3 = 13.227 lbs.

From (3), 1 + hyp log R = 13.227 ÷ 6 = 2.2045.

Hyp log R = 1.2045, whence R in l. p. cyl. = 3.335.

From (4), 3.335 × 6 = 20.01 lbs. initial pressure in l. p. cyl. and terminal pressure in h. p. cyl., assuming no drop between cylinders.

110 ÷ 22.01 = 18.33 ÷ 3.335 = 5.497, R in h. p. cyl.

From (3), mean total pres. in h. p. cyl. = 20.01 × (1 + hyp log 5.497) = 54.11.

From (2), 54.11 − 20.01 = 34.10, M.E.P. in h. p. cyl.

From (1), area of h. p. cyl. $= \frac{1000 \times 33{,}000}{700 \times 34.1} = 1382$ sq. ins. = 42 ins. diam.

Cylinder ratio = 4610 ÷ 1382 = 3.336.

The area of the h. p. cylinder may be found more directly by dividing the area of the l. p. cyl. by the ratio of expansion in that cylinder. 4610 ÷ 3.335 = 1382 sq. ins.

In the above calculation no account is taken of clearance, of compression, of drop between cylinders, nor of area of piston-rods. It also assumes that the diagram in each cylinder is the full theoretical diagram, with a horizontal steam-line and a hyperbolic expansion line, with no allowance for rounding of the corners. To make allowance for these, the mean effective pressure in each cylinder must be multiplied by a diagram factor, or the ratio of the area of an actual diagram of the class of engine considered, with the given initial and terminal pressures, to the area of the theoretical diagram. Such diagram factors will range from 0.6 to 0.94, as in the table on p. 745.

Best Ratios of Cylinders.—The question what is the best ratio of areas of the two cylinders of a compound engine is still (1901), a disputed one, but there appears to be an increasing tendency in favor of large ratios, even as great as 7 or 8 to 1, with considerable terminal drop in the high-pressure cylinder. A discussion of the subject, together with a description of a new method of drawing theoretical diagrams of multiple-expansion engines, taking into consideration drop, clearance, and compression, will be found in a paper by Bert C. Ball, in Trans. A. S. M. E., xxi. 1002.

TRIPLE-EXPANSION ENGINES.

Proportions of Cylinders.—H. H. Suplee, *Mechanics*, Nov. 1887, gives the following method of proportioning cylinders of triple-expansion engines:

As in the case of compound engines the diameter of the low-pressure cylinder is first determined, being made large enough to furnish the entire power required at the mean pressure due to the initial pressure and expansion ratio given; and then this cylinder is only given pressure enough to perform one third of the work, and the other cylinders are proportioned so as to divide the other two thirds between them.

Let us suppose that an initial pressure of 150 lbs. is used and that 900 H.P. is to be developed at a piston-speed of 800 ft. per min., and that an expansion ratio of 16 is to be reached with an absolute back pressure of 2 lbs.

The theoretical M.E.P. with an absolute initial pressure of 150 + 14.7 = 164.7 lbs. initial at 16 expansions is

$$\frac{P(1 + \text{hyp log } 16)}{16} = 164.7 \times \frac{3.7726}{16} = 38.83,$$

less 2 lbs. back pressure, = 38.83 − 2 = 36.83.

In practice only about 0.7 of this pressure is actually attained, so that 36.83 × 0.7 = 25.781 lbs. is the M.E.P. upon which the engine is to be proportioned.

To obtain 900 H.P. we must have 33,000 × 900 = 29,700,000 foot-pounds, and this divided by the mean pressure (25.78) and by the speed in feet (800) will give 1440 sq. in. for the area of the l. p. cylinder, about equivalent to 43 in. diam.

Now as one third of the work is to be done in the l. p. cylinder, the M.E.P. in it will be 25.78 ÷ 3 = 8.59 lbs.

The cut-off in the high-pressure cylinder is generally arranged to cut off at 0.6 of the stroke, and so the ratio of the h. p. to the l. p. cylinder is equal to 16 × 0.6 = 9.6, and the h. p. cylinder will be 1440 ÷ 9.6 = 150 sq. in. area, or about 14 in. diameter, and the M.E.P. in the h. p. cylinder is equal to 9.6 × 8.59 = 82.46 lbs.

If the intermediate cylinder is made a mean size between the other two, its size would be determined by dividing the area of the l. p. cylinder by the square root of the ratio between the low and the high; but in practice this is found to give a result too large to equalize the stresses, so that instead the area of the int. cylinder is found by dividing the area of the l. p. piston by 1.1 times the square root of the ratio of l. p. to h. p. cylinder, which in this case is 1440 ÷ (1.1 $\sqrt{9.6}$) = 422.5 sq. in., or a little more than 23 in. diam.

The choice of expansion ratio is governed by the initial pressure, and is generally chosen so that the terminal pressure in the l. p. cylinder shall be about 10 lbs. absolute.

Formulæ for Proportioning Cylinder Areas of Triple-Expansion Engines.—The following formulæ are based on the method of first finding the cylinder areas that would be required if an ideal hyperbolic diagram were obtainable from each cylinder, with no clearance, compression, wire-drawing, drop by free expansion in receivers, or loss by cylinder condensation, assuming equal work to be done in each cylinder, and then dividing the areas thus found by a suitable diagram factor, such as those given on page 745, expressing the ratio which the area of an actual diagram, obtained in practice from an engine of the type under consideration, bears to the ideal or theoretical diagram. It will vary in different classes of engine and in different cylinders of the same engine, usual values ranging from 0.6 to 0.9. When any one of the three stages of expansion takes place in two cylinders, the combined area of these cylinders equals the area found by the formulæ.

NOTATION.

p_1 = initial pressure in the high pressure cylinder.
p_t = terminal " " " low pressure "
p_b = back " " " " " "

p_2 = term. press. in h. p. cyl. and initial press. in intermediate cyl.
p_3 = " " " int. " " " " " l. p. cyl.
R_1, R_2, R_3, ratio of exp. in h. p. int. and l. p. cyls.
R = total ratio of exp. = $R_1 \times R_2 \times R_3$.
P = mean effec. press. of the combined ideal diagram, referred to the l. p. cyl.

P_1, P_2, P_3 = m. e. p. in the h. p., int., and l. p. cyls.
HP = horse-power of the engine = $PLA_3N \div 33{,}000$.
L = length of stroke in feet; N = number of single strokes per min.
A_1, A_2, A_3, areas (sq. ins.) of h. p. int. and l. p. cyls. (ideal).
W = work done in one cylinder per foot of stroke.
r_2 = ratio of A_2 to A_1; r_3 = ratio of A_3 to A_1.
F_1, F_2, F_3, diagram factors of h. p. int. and l. p. cyl.
a_1, a_2, a_3, areas (actual) of " " " " "

Formulæ.

(1) $R = p_i \div pt$.
(2) $P = pt(1 + \text{hyp. log. } R) - pb$.
(3) $P_3 = \frac{1}{3}P$.
(4) Hyp. log. $R_3 = (P_3 - p_t + pb) \div p_t$.

(5) $R_1R_2 = R \div R_3$; $R_1 = R_2 = \sqrt{R_1R_2}$.
(6) $p_3 = pt \times R_3$.
(7) $p_2 = p_3 \times R_2$.
(8) $p_1 = p_2 \times R_1$.
(9) $P_2 = p_3(\text{hyp. log. } R_2) = P_3R_3$.
(10) $P_1 = p_2(\text{hyp. log. } R_1)P_2R_2$.
(11) $W = 11{,}000\ HP \div LN$.
(12) $A_1 = W \div P_1$; $A_2 = W \div P_2$; $A_3 = W \div P_3$.
(13) $r_2 = A_2 \div A_0 = P_1 \div P_1 = R_1$ or R_2; $r_3 = A_3 \div A_1 = P_1 \div P_3$.
(14) $a_1 = A_1 \div F_1$; $a_2 = A_2 \div F_2$; $a_3 = A_3 \div F_3$.

From these formulæ the figures in the following tables have been calculated:

THEORETICAL MEAN EFFECTIVE PRESSURES, CYLINDER RATIOS, ETC., OF TRIPLE EXPANSION ENGINES.

Back pressure, 3 lbs. Terminal pressure, 8 lbs. (absolute).

p_1.	R.	P.	P_3.	R_3.	R_1, R_2, or r_2.	p_3.	p_2.	P_2.	P_1.	r_3.
120	15	26.66	8.89	1.626	3.037	13.01	39.51	14.45	43.89	4.939
140	17.5	27.90	9.30	1.712	3.197	13.70	43.79	15.92	50.89	5.472
160	20	28.97	9.66	1.790	3.343	14.32	47.86	17.29	57.76	5.980
180	22.5	29.91	9.97	1.861	3.477	14.89	51.77	18.55	64.52	6.471
200	25	30.75	10.25	1.928	3.601	15.42	55.54	19.76	71.16	6.942
220	27.5	31.51	10.50	1.990	3.718	15.91	59.16	20.90	77.69	7.397
240	30	32.21	10.74	2.049	3.826	16.39	62.72	22.00	84.16	7.839

Back pressure, 3 lbs. Terminal pressure, 10 lbs. (absolute).

p_1.	R.	P.	P_3.	R_3.	R_1, R_2, or r_2.	p_3.	p_2.	P_2.	P_1.	r_3.
120	12	31.85	10.62	1.436	2.890	14.36	41.50	15.24	44.04	4.148
140	14	33.39	11.13	1.511	3.044	15.11	45.99	16.82	51.20	4.600
160	16	34.73	11.58	1.580	3.182	15.80	50.28	18.29	58.20	5.027
180	18	35.90	11.97	1.643	3.310	16.43	54.38	19.66	65.09	5.439
200	20	36.96	12.32	1.702	3.428	17.02	58.31	20.97	71.88	5.834
220	22	37.91	12.64	1.757	3.538	17.57	62.15	22.20	78.54	6.215
240	24	38.78	12.93	1.809	3.642	18.09	65.88	23.38	85.15	6.587

Given the required H.P. of an engine, its speed and length of stroke, and the assumed diagram factors F_1, F_2, F_3 for the three cylinders, the areas of the cylinders may be found by using formulæ (11), (12), and (14), and the values of P_1, P_2, and P_3 in the above table.

A Common Rule for Proportioning the Cylinders of multiple-expansion engines is: for two-cylinder compound engines, the cylinder ratio is the square root of the number of expansions, and for triple-expansion engines the ratios of the high to the intermediate and of the intermediate to the low are each equal to the cube root of the number of expansions, the ratio of the high to the low being the product of the two ratios, that is, the square of the cube root of the number of expansions. Applying this rule to the pressures above given, assuming a terminal pressure (absolute) of 10 lbs. and 8 lbs. respectively, we have, for triple-expansion engines:

Boiler-pressure (Absolute).	Terminal Pressure, 10 lbs.		Terminal Pressure, 8 lbs.	
	No. of Expansions.	Cylinder Ratios, areas.	No. of Expansions.	Cylinder Ratios, areas.
130	13	1 to 2.35 to 5.53	16¼	1 to 2.53 to 6.42
140	14	1 to 2.41 to 5.81	17½	1 to 2.60 to 6.74
150	15	1 to 2.47 to 6.08	18¾	1 to 2.66 to 7.06
160	16	1 to 2.52 to 6.35	20	1 to 2.71 to 7.37

The ratio of the diameters is the square root of the ratios of the areas, and the ratio of the diameters of the first and third cylinders is the same as the ratio of the areas of first and second.

Seaton, in his Marine Engineering, says: When the pressure of steam employed exceeds 115 lbs. absolute, it is advisable to employ three cylinders, through each of which the steam expands in turn. The ratio of the low-pressure to high-pressure cylinder in this system should be 5, when the steam-pressure is 125 lbs. absolute; when 135 lbs. absolute, 5.4; when 145 lbs. absolute, 5.8; when 155 lbs. absolute, 6.2; when 165 lbs. absolute, 6.6. The ratio of low-pressure to intermediate cylinder should be about one half that between low-pressure and high-pressure, as given above. That is, if the ratio of l. p. to h. p. is 6, that of l. p. to int. should be about 3, and consequently that of int. to h. p. about 2. In practice the ratio of int. to h. p. is nearly 2.25, so that the diameter of the int. cylinder is 1.5 that of the h. p. The introduction of the triple-compound engine has admitted of ships being propelled at higher rates of speed than formerly obtained without exceeding the consumption of fuel of similar ships fitted with ordinary compound engines; in such cases the higher power to obtain the speed has been developed by decreasing the rate of expansion, the low-pressure cylinder being only 6 times the capacity of the high-pressure, with a working pressure of 170 lbs. absolute. It is now a very general practice to make the diameter of the low pressure cylinder equal to the sum of the diameters of the h. p. and int. cylinders; hence,

Diameter of int. cylinder = 1.5 diameter of h. p. cylinder;
Diameter of l. p. cylinder = 2.5 diameter of h. p. cylinder.

In this case the ratio of l. p. to h. p. is 6.25; the ratio of int. to h. p. is 2.25; and ratio of l. p. to int. is 2.78.

Ratios of Cylinders for Different Classes of Engines. (Proc. Inst. M. E., Feb. 1887, p. 36.)—As to the best ratios for the cylinders in a triple engine there seems to be great difference of opinion. Considerable latitude, however, is due to the requirements of the case, inasmuch as it would not be expected that the same ratio would be suitable for an economical land engine, where the space occupied and the weight were of minor importance, as in a war-ship, where the conditions were reversed. In the land engine, for example, a theoretical terminal pressure of about 7 lbs. above absolute vacuum would probably be aimed at, which would give a ratio of capacity of high pressure to low pressure of 1 to 8½ or 1 to 9; whilst in a war-ship a terminal pressure would be required of 12 to 13 lbs. which would need a ratio of capacity of 1 to 5; yet in both these instances the cylinders were correctly proportioned and suitable to the requirements of the case. It is obviously unwise, therefore, to introduce any hard-and-fast rule.

Types of Three-stage Expansion Engines. 1 Three cranks at 120 deg. 2. Two cranks with 1st and 2d cylinders tandem. 3. Two cranks with 1st and 3d cylinders tandem. The most common type is the first, with cylinders arranged in the sequence high, intermediate, low.

Sequence of Cranks.—Mr. Wyllie (Proc. Inst. M. E., 1887) favors the sequence high, low, intermediate, while Mr. Mudd favors high, intermediate, low. The former sequence, high, low, intermediate, gave an approximately horizontal exhaust-line, and thus minimizes the range of temperature and the initial load; the latter sequence, high, intermediate, low, increased the range and also the load.

Mr. Morrison, in discussing the question of sequence of cranks, presented a diagram showing that with the cranks arranged in the sequence high, low, intermediate, the mean compression into the receiver was 19½ per cent of the stroke; with the sequence high, intermediate, low, it was 57 per cent. In the former case the compression was just what was required to keep the receiver-pressure practically uniform; in the latter case the compression caused a variation in the receiver-pressure to the extent sometimes of 22½ lbs.

Velocity of Steam through Passages in Compound Engines. (Proc. Inst. M. E., Feb. 1887.)—In the SS. *Para*, taking the area of the cylinder multiplied by the piston-speed in feet per second and dividing by the area of the port the velocity of the initial steam through the high-pressure cylinder port would be about 100 feet per second; the exhaust would be about 90. In the intermediate cylinder the initial steam had a velocity of about 180, and the exhaust of 120. In the low-pressure cylinder the initial steam entered through the port with a velocity of 250, and in the exhaust-port the velocity was about 140 feet per second.

QUADRUPLE-EXPANSION ENGINES.

H. H. Suplee (Trans. A. S. M. E., x. 583) states that a study of 14 different quadruple-expansion engines, nearly all intended to be operated at a pressure of 180 lbs. per sq. in., gave average cylinder ratios of 1 to 2, to 3.78, to 7.70, or nearly in the proportions 1, 2, 4, 8.

If we take the ratio of areas of any two adjoining cylinders as the fourth root of the number of expansions, the ratio of the 1st to the 4th will be the cube of the fourth root. On this basis the ratios of areas for different pressures and rates of expansion will be as follows:

Gauge-pressures.	Absolute Pressures.	Terminal Pressures.	Ratio of Expansion.	Ratios of Areas of Cylinders.
160	175	12	14.6	1 : 1.95 : 3.81 : 7.42
		10	17.5	1 : 2.05 : 4.18 : 8.55
		8	21.9	1 : 2.16 : 4.68 : 10.12
180	195	12	16.2	1 : 2.01 : 4.02 : 8.07
		10	19.5	1 : 2.10 : 4.42 : 9.28
		8	24.4	1 : 2.22 : 4.91 : 10.98
200	215	12	17.9	1 : 2.06 : 4.23 : 8.70
		10	21.5	1 : 2.15 : 4.64 : 9.98
		8	26.9	1 : 2.28 : 5.19 : 11.81
220	235	12	19.6	1 : 2.10 : 4.43 : 9.31
		10	23.5	1 : 2.20 : 4.85 : 10.67
		8	29.4	1 : 2.33 : 5.42 : 12.62

Seaton says: When the pressure of steam employed exceeds 190 lbs. absolute, four cylinders should be employed, with the steam expanding through each successively; and the ratio of l. p. to h. p. should be at least 7.5, and if economy of fuel is of prime consideration it should be 8; then the ratio of first intermediate to h. p. should be 1.8, that of second intermediate to first int. 2, and that of l. p. to second int. 2.2.

In a paper read before the North East Coast Institution of Engineers and Shipbuilders, 1890, William Russell Cummins advocates the use of a four-cylinder engine with four cranks as being more suitable for high speeds than the three-cylinder three-crank engine. The cylinder ratios, he claims, should be designed so as to obtain equal initial loads in each cylinder. The ratios determined for the triple engine are 1, 2.04, 6.54, and for the quadruple, 1, 2.08, 4.46, 10.47. He advocates long stroke, high piston-speed, 100 revolutions per minute, and 250 lbs. boiler-pressure, unjacketed cylinders, and separate steam and exhaust valves.

Diameters of Cylinders of Recent Triple-expansion Engines, Chiefly Marine.

Compiled from several sources, 1890-1893.

Diam. in inches: H = high pressure, I = intermediate, L = low pressure.

H	*I*	*L*	*H*	*I*	*L*	*H*	*I*	*L*	*H*	*I*	*L*
3	5	8	16	25.6	41	22	36	40	36	58	94
4¾	7.5	13	16¼	23⅞	38.5			40	38	61.5	100
5	8	12	16.5	24.5	31	23	38	61	28	56	86
6.5	10.5	16.5			31	23.5	38	60	28		
7	9	12.5	17	27	44	24	37	56	39	61	97
7.1	11.8	18.9	17	26.5	42	25	40	64	40	59	88
7.5	12	19	17	28	45	26	42	69	40	67	106
8	11.5	16	18	27	40	26	42.5	70	40	66	100
9	14.5	22.5	18	29	48	28	44	72	41	66	101
9.8	15.7	25.6	18	305.	51	29⅜	44	70	41⅜	67	106¾
10	16	25	18.7	29.5	43.3	29.5	48	78	42	59	92
11	16	24	18¾	23.6	35.4	30	48	77	43	66	92
11	18	25	19.7	29.6	47.3	32	46	70	43	68	110
11	18	30	20	30	45	32	51	82	43⅜	67	106¼
11.5	18	28.5	20	32.5	36	32	54	82	45	71	113
11.5	17.5	30.5			36	33	58	88	32.5	68	85.7
12	19.2	30.7	20	33	52	33.9	55.1	84.6	32.5		85.7
13	22	33.5	21	32	48	34	51	85	47	75	81.5
14	22.4	36	21	36	51	31	50	90			81.5
14.5	24	39	21.7	33.5	49.2	34.5	51	85	37	79	98
15	24	39	21.9	34	57	34.5	57	92	37		98
15	24.5	38	22	34	51						

Where the figures are bracketed there are two cylinders of a kind. Two 28″ = one 39.6″, two 31″ = one 43.8″, two 32.5″ = one 46.0″, two 36″ = one 50.9″, two 37″ = one 52.3″, two 40″ = one 56.6″, two 81.5″ = one 115″, two 85.7″ = one 121″, two 98″ = one 140″. The average ratio of diameters of cylinders of all the engines in the above table is nearly 1 to 1.60 to 2.56 and the ratio of areas nearly 1 to 2.56 to 6.55.

The Progress in Steam-engines between 1876 and 1893 is shown in the following comparison of the Corliss engine at the Centennial Exhibition in 1876 and the Allis-Corliss quadruple-expansion engine at the Chicago Exhibition.

	1893.	1876.
Engine	Quadruple-expansion.	Simple
Cylinders, number	4	2
" diameter	24, 40, 60, 70 in.	40 in.
" stroke	72 in.	120 in.
Fly-wheel, diameter	30 ft.	30 ft.
" width of face	76 in.	24 in.
" weight	136,000 lbs.	125,440 lbs.
Revolutions per minute	60	36
Capacity, economical	2000 H.P.	1400 H.P.
" maximum	3000 H.P.	2500 H.P.
Total weight	650,000 lbs.	1,360,588 lbs.

The crank-shaft body or wheel-seat of the Allis engine has a diameter of 21 inches, journals 19 inches, and crank bearings 18 inches, with a total length of 18 feet. The crank-disks are of cast iron and are 8 feet in diameter. The crank-pins are 9 inches in diameter by 9 inches long.

A Double-tandem Triple-expansion Engine, built by Watts, Campbell & Co., Newark, N. J., is described in *Am. Mach.*, April 26, 1894. It is two three-cylinder tandem engines coupled to one shaft, cranks at 90°, cylinders 21, 32 and 48 by 60 in. stroke, 65 revolutions per minute, rated H.P. 2000; fly-wheel 28 feet diameter, 12 ft. face, weight 174,000 lbs.; main shaft 22 in. diameter at the swell; main journals 19 × 38 in.; crank-pins 9½ × 10 in.; distance between centre lines of two engines 24 ft. 7⅛ in.; Corliss valves, with separate eccentrics for the exhaust-valves of the l.p. cylinder.

Engines in the Power Plant at the World's Columbian Exposition, 1893.

Type of Engine.	Horizontal or Vertical.	Cylinders, ins. Diameters and Stroke.	I.H.P. Maximum Economy.	I.H.P. Maximum Load.	Driv. Pulley, Diameter in. Face, in.	Revolutions per Minute.	Size of Steam-pipe.	Size of Exhaust-pipe.	Weight of Engine, lbs.
Quad. exp. condensing	H.	24, 40, 60, 70 x 72	2,000	3,000	360 x 76	60	10	22	650,000
4-cyl. trip. exp. cond	"	20, 34, 2-34 x 60	1,000	1,250	336 x 68	64 1-2	7	16	260,000
Double tand. comp. cond.	"	18, 32 x 36 double	1,000	1,500	192 x 78	112	7	14	250,000
4-cyl. trip. exp. cond	"	20, 30, 2-36 x 48	1,000	1,300	240 x 75	85	8	12	120,000
Comp. condensing	"	14, 24 x 30	1,000	1,300	144 x 75	150	5	8	114,000
Comp. cond., 6 engines	V.	21 1-2, 37 x 22	1,000	......	132 x 14	200	10	14	195,000*
" " 2 "	"	18, 30 x 16	350	......	96 x 26	250	8	10	......
Double tand. comp. cond.	H.	15, 24 x 24	506	897	120 x 60	125	7	12	83,298
Tandem comp. cond	"	14, 24 x 30	500	650	144 x 36	150	5	8	57,000
Cross compound cond	"	16, 30 x 42	224	440	192 x 43	70	5	10	61,000
" " "	"	16, 30 x 42	300	350	192 x 43	70	5	10	80,000
Tandem comp. cond	"	16, 28 x 42	300	350	216 x 36	80	5	10	75,000
Double tand. comp. cond.	"	9, 16 x 14	250	......	60 x 12	250	4 1-2	10	21,200
Cross compound cond	"	14, 28 x 24	300	360	120 x 33	50	......	......	33,000
Cross compound	"	14, 22 x 12	200	250	66	280	5	8	......
Simple	"	15 1-2 x 16	150	200	72 x 12	250	4 1-2	6	......
Triple exp. condensing	V.	23, 37, 57 x 27	1,000	......	......	100	......	......	......
Tandem comp. cond	H.	19, 31 x 24	600	800	102 x 31	165	7	12	75,000
4-cyl. trip. exp. cond	"	15, 24, 2-26 x 18	500	......	2-108 x 26 1-108 x 38	200	6	14	......
Tandem compound cond.	"	13, 24 x 18	250	......	108 x 26	200	5	9	......
" " "	"	13, 22 x 16	225	250	72 x 16 1-2	245	6	8	24,000
Cross compound cond	"	19, 36 x 48	500	800	192	90	7	12	85,000
Triple exp. condensing	V.	......	1,000	......	......	......	8	18	......
Simple	H.	18 x 21	......	......	84 x 25	225	7	10	......
Cross compound	"	18, 36 x 18	480	570	86	225	7	18	65,000
Tandem compound cond.	"	14, 23 x 20	220	325	84 x 29	200	5	10	24,000
Simple	"	24 x 48	350	425	192 x 44	......	8	9	49,000
Tandem compound	"	12, 22 x 30	200	270	132 x 25	115	4	7 1-2	35,000
Simple	"	20 x 48	297	346	192 x 27	60	6	7	43,000
Tandem compound	"	17, 28 x 18	300	370	102 x 31	176	6	11	50,000
" "	"	12, 20 x 42	225	300	144 x 25	125	5	8	49,600
Simple	"	18 x 22	300	390	84 x 24 1-2	160	6	7	18,000
Comp. condensing	"	17, 30 x 45	350	......	282	70	......	......	......
Comp. cond., 3-throw	V.	3-14, 20 x 8	......	360	58 x 40	350	4	5	......
Triple exp. condensing	"	12, 19, 29 1-2 x 14	150	......	......	150	......	......	......

* Engine and dynamo.

INDEX TO PHOTOS ON CD

SPIRIT OF JOPLIN AIR CAR: TERRY MILLER, INVENTOR

Send $10 for CD with engine construction photos

PAGE IN BOOK	PICTURE DESCRIPTION
	REFERENCED IN TAPE TRANSCRIPTION
98	3rd and 4th stage cylinders (low pressure engine)
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100	all 4 stages (both engines)
	ENGINE SHOWN IN CAR
101	one motor frame installed
102	both motor frames installed (from above)
103	both motor frames installed (from above)
104	both motor frames installed (from above)
105	motor frames and crank gears installed (from front)
106	motor frames and crank gears installed (from side)
107	cylinders and valves installed
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Thanks, Terry!